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WASTE OIL RECYCLING AND DISPOSAL

Recon Systems, Incorporated

PREPARED FOR
Environmental Protection Agency
Response Analysis Corporation

August 1974

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~~This study has developed~~ information was developed on sources and quantities of waste oils, current and potential recycle and disposal methods, and the environmental impact of these methods. In addition to an extensive literature search, surveys (of rerefiners, collectors and processors, the Pittsburgh Pennsylvania Metro area and Standard Industrial Classification groups) were conducted to develop information reported. (EPA)

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WASTE OIL RECYCLING AND DISPOSAL

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Contract Nos. 68-01-1870
and 68-03-0394

Program Element No. 1BB041

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and

- a search for ways to prevent contamination and to recycle valuable resources.

Little quantitative information has been available on the ultimate fate of waste oil generated from the 2.2. billion gallons of lubricating and industrial oils used annually in the United States. In this study information has been developed on sources and quantities of waste oils, current and potential recycle and disposal methods, and the environmental impact of these methods.

A. W. Breidenbach, Ph.D.
Director
National Environmental
Research Center, Cincinnati

ABSTRACT

Little quantitative information has been available as to the ultimate disposal of the 2.2 billion gallons per year of lubricating and industrial oils used in the U. S.; or of additional waste oils resulting from production, transportation, refining, and use of petroleum and its products. About 100 million gallons per year is known to be recycled by the re-refining industry, producing lubricating oils; and other oil is used as fuel, road oil, and a variety of other applications. Each of these applications, including re-refining, has substantial negative impacts on the environment. In this study, information has been developed on sources and quantities of waste oils, current and potential recycle and disposal methods, and the environmental impact of these methods.

Several surveys were conducted to aid in the development of the desired information. These included:

1. Visits to 30 re-refiners and waste oil processors, primarily to obtain technical information.
2. A waste oil survey of the Pittsburgh area, including interviews with 83 service stations, various industrial organizations, waste oil collectors and processors, and others.
3. A nationwide telephone survey of 92 collectors and processors of waste oil.
4. A combined telephone and visit survey of organizations in 57 Standard Industrial Classification major groups.

Other data were obtained through an extensive literature search, and by actual sampling of wastewaters in two waste oil processing plants.

An estimated 2.5 billion gallons per year of all types of waste oils are generated. The majority of these ultimately find their to the environment or are used as fuel. A relatively small quantity is re-refined to lubricating oils.

Acid/clay treatment, the most commonly used re-refining process for waste lubricating oils, is not an attractive approach for expanding the re-refining industry, because of its high cost and because of undesirable waste products produced (acid sludge, spent clay). More attractive processes are available, but further development work is required.

Use of vehicular waste oils for fuel, road oiling, and dust control, currently major uses, is unsound from the points of view of resource and environment conservation. During combustion, very fine lead particles are emitted to the atmosphere. Waste oils generally make poor road oils, resulting in rapid loss of oil to the surrounding land and waters.

Much industrial waste oil is being recovered and reused internally and externally, including considerable fuel usage, but an uncomfortable quantity is being indiscriminately disposed of in road oiling, dust control, dumps, and landfills. The disposal of oily flocs and sludges from wastewater treatment is a major industrial problem.

Recommendations are made to encourage the expansion of a technically and environmentally sound oil recycling industry, including licensing of collectors and processors, and a research and development program.

This report was submitted in fulfillment of Contract Nos. 68-01-1870 and 68-03-0394 by Recon Systems, Inc. and Response Analysis Corporation under the sponsorship of the U.S. Environmental Protection Agency.

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SECTION I
CONCLUSIONS

WASTE OIL QUANTITY

1. Insufficient information is available to accurately estimate the total quantities of waste oil generated, available for recycle, or disposed of improperly.

2. Best approximations, based primarily on sales figures, has produced the following estimates for waste oil generation:

	Millions of Gal./Yr.
Automotive lubricating oil	616
Industrial & aviation lubricating oil	394
Other industrial oils	87
U.S. Government lubricating oil	18
Marine oil transportation losses and spills	209
Other oil losses in production, refining, transportation and use	1,156
Total for Petroleum	2,480
Oil and Fat Industry Losses	13
Coke Oven Oil Losses	6
	2,499

3. The ultimate destination of these oils was also deduced from limited available survey information:

	Millions of Gal/Yr.	
Directly to the environment	978	
Processing wastes to the environment	72	
Road oil, dust control, runoff, asphalt leaching, land disposal, residue to the environment	281	
Sub-total-to the Environment		1,331
Directly for use as fuels	358	
Use for processing plant fuels	49	
Fuels sold by oil processors	621	
Sub-total-Fuels		1,028
Road oil and dust control-rapid biodegradation	38	
Re-refined oil sales	83	
Sub-total-Other		121
Total for Petroleum		2,480

4. The 1,331 million gallons per year of oil which may be reaching the environment represents 0.6% of total crude oil, refined products and natural gas liquids produced and imported (231 billion gallons in 1971). About half of these losses to the environment was estimated to have come from production; refining; transportation; and use of oil--as spills; wastewater discharges; land, ocean, and deepwell disposal of wastewater treatment sludges and flocs, tank cleaning residues, and coke; land spreading of contaminated oils; evaporation; and other miscellaneous losses.

5. Less than 10% of the total potential lubricating oils are recovered.

WASTE OIL RECYCLE AND DISPOSAL

1. Fewer than 40 re-refiners producing lube oils remain out of an industry that once numbered 150.

2. The single most difficult problem existing in the re-refining industry today is inability to compete for available crankcase drain oils and industrial waste lubricating oils with fuel, road oil, and dust control applications.

3. Acid/clay treatment, the most commonly used re-refining process for lubricating waste oils, is not an attractive approach for expanding the re-refining industry because of its high cost and because of undesirable waste products produced.

4. The solvent extraction/acid/clay treatment process is more attractive economically, but it also produces waste products, though in smaller quantities.

5. The distillation/clay process appears to be an attractive approach to re-refining, though a more detailed evaluation and additional development work is required to assure product quality, reliable operation, and proper disposal of the distillation bottoms product and spent clay.

6. The distillation/hydrogen treating process is the only re-refining scheme available which holds promise for economical vehicular waste oil recycle without producing waste products, assuming that distillation bottoms find an outlet in secondary lead smelting.

7. Most re-refiners are so harassed by adverse business conditions that they are unable to finance necessary plant improvements.

8. In addition to the re-refining industry, a second group of oil reclaimers, designated here as waste oil processors, are engaged in converting waste oils to fuels and other products.

9. Treatment systems used by waste oil processors range from simple settling to filtration and to distillation.

10. With a few exceptions, the treatment systems used by waste oil processors have very limited utility in removing impurities such as lead particles, other fine particulates, and polymer precursors.

11. Uncontrolled use of lead-containing vehicular waste oils as a fuel is a poor approach to disposal because of lead and other fine particulate emissions, and because of the loss of important natural resources in short supply, namely lead and lubricating oil stocks.

12. Uncontrolled burning of all waste automotive crankcase oil (approximately 500 million gallons per year) could result in as much as 40 million pounds per year of lead entering the atmosphere as fine particulates. This represents about 4% of U. S. mine production.

13. The use of vehicular waste oils for dust control and road oiling is wasteful and potentially harmful to the environment.

14. An appreciable fraction of industrial waste oils are purified and recycled to their original use.

15. A major fraction of industrial waste oils are used as fuel at the point of generation, or converted to fuel use by the collector.

16. A major fraction of industrial waste oils reach the environment by consumption during use (oxidation, vaporization), by land disposal, dust control uses, and loss to wastewater effluents.

17. Very few industrial concerns have records of the ultimate disposal of wast oils purchased.

18. The collection of waste oils from automotive service stations, industrial plants, and other points of generation is haphazard and inefficient.

19. Of the waste oil picked up by collectors, more than one-half is used as or blended with fuels, with little or no control of quality; major quantities are used for road oiling and dust control, with little or no environmental control; major quantities are processed to lube oil and other products; and unknown quantities enter the environment by disposal on land, and loss to wastewater.

ENVIRONMENTAL IMPACT OF WASTE PRODUCTS

Insufficient information is available to fully evaluate important aspects of environmental impact. Therefore, the following conculsions should be considered as tentative.

1. Acid sludge, in the relatively small quantities now produced by individual re-refiners (about 200-5000 gallons per day), can be disposed of safely in landfills, if proper handling and disposal practices are followed.

2. Disposal of spent clay, by re-refiners and others recycling waste oil, in landfills does not appear to present serious environmental problems if proper practices are followed.

3. Wastewater quantities discharged by waste oil re-refiners and reprocessors is generally small but oil contamination problems are common.

4. Odor and other air pollution problems from waste oil re-refiners and processors are generally minor.

5. Water and air emissions can be adequately controlled by existing technology.

SECTION II

RECOMMENDATIONS

1. Federal and State governments should encourage expansion of the re-refining industry to produce lubricating oils from automotive and industrial lubes. This can be accomplished by:

   a. Controlling the use of lead-containing oils as fuels, whether or not they are diluted with other fuels, by specifying that air pollution control devices be provided to efficiently remove lead and other particulates.

   b. Requiring that all parties engaged in the sale of oils at any level disclose the source and characteristics of waste oils, especially contents of lead or other hazardous materials which may be in the oil sold.

   c. Establishing minimum specifications of oils suitable for roads, dust control, and asphalt, emphasizing lead content and other environmental aspects. A research program would be required to establish these criteria.

   d. Licensing all waste oil collectors, processors, and waste disposal facilities; and setting minimum standards of performance, including requirements that collectors dispose of waste oil to a licensed processor, and that processors dispose of wastes to a licensed waste disposal facility.

   e. Examining the implication of tax policies for virgin lubricating oil sales versus re-refined oil sales to at least eliminate those policies which discourage oil recycle.

   f. Requiring that all retail establishments selling lubricating oils provide a waste oil disposal facility.

g. Requiring that all establishments which purchase more than 500 gallons per year of lubricating oils provide a suitable segregated disposal facility for the waste oil or obtain an exemption on the grounds that waste oils are not produced.

h. Encouraging governmental use of re-refined oils, including the performance of engine tests when such tests are required to meet product specifications. The re-refiner should perform standard chemical and physical tests on oils at his own expense.

i. Recognizing that the re-refiner is an essential element in pollution control programs by allowing him access to funding with tax-free pollution control revenue bonds, and by encouraging Small Business Administration support where applicable.

j. Allowing the use of the description "recycled oil" on lubricating oil containers, along with a definition of that term.

k. Specifying minimum size storage tanks for waste oils in service stations (approximately 500 gallons would be suitable).

l. Supporting research and development and grant programs to improve re-refining and waste disposal technology.

2. Federal and State governments should also encourage the expansion of a processing industry which handles industrial, marine, and other waste oils which are not of the lubricating type by:

    a. Requiring that adequate records of purchase, recycle, and disposal be kept.

    b. Requiring adequate waste oil segregation when large quantities are involved.

    c. Requiring disclosure of oil composition with respect to hazardous materials when oil sales or other oil transfers are made.

d. Licensing collectors, processors, and waste oil disposal facilities.

e. Encouraging governmental use of reprocessed oils.

f. Allowing the processor access to funding with tax-free pollution control revenue bonds, and by encouraging Small Business Administration support where applicable.

g. Supporting research and development and grant programs to characterize industrial oils and to develop improved recycle and disposal techniques.

3. A few specific research and development programs which appear to merit Federal support, in addition to those previously mentioned, are:

a. The chemical and physical characterization of acid sludge, spent clay and other waste to aid the assessment of environmental impract.

b. Studies of the effect of the above wastes in landfills.

c. Completion of the development of a vacuum distillation/hydrogen treatment process for re-refining, include the use of distillation bottoms in secondary lead smelting.

d. Investigation of the use of crankcase waste oil and other waste oils as chemical raw materials.

e. Work to improve oil recovery from marine transportation and oil spill wastes, and to clean up the resulting wastewater.

SECTION III

INTRODUCTION

The non-polluting disposal of waste oils in the United States is a problem of enormous complexity because it involves not only the hundreds of thousands of establishments using fuels and lubricants, but also the hundred million vehicles and over 400,000 service stations, garages, and auto dealers which service these vehicles. Little quantitative information is available as to the ultimate disposal of the 2.2 billion gallons per year of lubricating and industrial oils used in the U. S.; or of additional waste oils resulting from production, transportation, refining, and use of petroleum and its products; or of waste oils from other sources such as animal, fish, and vegetable oils and fats, and coking ovens.

A waste oil re-refining industry has existed in the U. S. for many years, converting waste lubricating oils to usable lubricants. However, in recent years the number of re-refiners has decreased from about 150 to less than 40. This fact has caused concern as to the disposition of waste oils.

Less is known about another group of oil reclaiming concerns, most of which convert a variety of waste oils to fuels. For purposes of this report, these concerns are called waste oil processors, although this description sometimes refers to all oil reclaimers.

Information has been developed on quantities of waste oils, current and potential recycle and disposal methods, and the environmental impace of these methods. To assess current disposal techniques, over 150 re-refiners, processors, collectors, and industrial organizations were surveyed, many by plant visits.

Literature information and the Contractor's background in petroleum refining and environmental problems provided the primary basis for assessing processes with potential for waste oil re-refining, and for the environmental assessment of waste discharges.

Preliminary waste oil material balances were made with the aid of data collected and previous surveys reported in the literature.

SECTION IV

CLASSIFICATION OF WASTE OILS

In order to consider waste oil recycling and disposal, it is important to understand the wide variety of sources and of composition. Waste oils are classified here primarily by point of generation, a system which closely parallels data available on oil sales. Each waste oil classification is briefly discussed, providing data on composition, volumes, and present recycle and disposal methods. Waste oil volumes discussed here are developed in Section X.

AUTOMOTIVE SERVICE CENTERS

This classification includes service stations, garages, new car dealers, other retail establishments, and automotive fleet service areas where used oils are drained from crankcases of automobiles and some trucks. The drain oils are generally collected in underground tanks having capacities in excess of 500 gallons, but occasionally above ground in drums or other containers. The drain oils consist primarily of crankcase waste oils (greater than 90%), but also include waste transmission fluids, gear lubricants, hydraulic oils, and minor amounts of kerosene and other solvents used in service areas. Some oil is disposed of to solid waste collection with the discard of oil filters.

Sales of lubricating oils by automotive service centers has been estimated to be 658 million gallons per year as shown in Table F-7. After correcting for factory fills and waste oils originating in discount store sales, about 500 million gallons per year of waste oil are estimated as generated in automotive service centers. This is the largest relatively uniform source of waste oil available for recycling.

Typical compositions of drain oil are shown in Tables 1 and 2. The most pertinent features of this oil with regard to recycle and disposal problems, are flash point, and water, sediment, ash, nitrogen, and oxygen contents. Many of the impurities are emulsified and very difficult to remove. The stability of the emulsions is enhanced by additives in the original lubricating oil. The drain oils are normally somewhat acidic in nature.

Water content is generally about 3-5%, but may range from less than 1% to 10% or more. Some water results from gasoline combustion, but the very high water contents prob-

Table 1. ASSAY OF AUTOMOTIVE CRANKCASE DRAIN OILS BY ESSO[1]

Test	New York	California	Texas(A)	Texas(B)	New Jersey
Flash, COC, °F....	360	325	340	350	400
Vis @ 100°F, SSU..	319	441	404	494	549
Vis @ 210°F, SSU..	59.6	71.2	69.6	70.0	95.8
Viscosity index...	141	149	156	127	196
Grav., °API.......	24.4	23.1	24.6	23.3	22.0
Rob. color........	Black	Black	Black	Black	Black
Pour point, °F....	< -35	< -35	< -45	< -35	< -30
Neut. No..........	7.31	4.33	4.36	6.10	5.52
Con. carbon.......	5.20	4.68	3.80	4.93	5.06
KF water, %.......	0.11	0.26	0.44	0.051	0.41
Water by dist., %.	......	0.4	0.6	0.1	0.8
Nitrogen, wt. %...	0.16	0.21	0.13	0.13	0.17
Sulfur, wt. %.....	0.32	0.31	0.30	0.26	0.28
Oxygen, wt. %.....	1.36	1.80	1.83	1.44	2.25
Zinc, wt. %.......	0.098	0.069	0.084	0.085	0.067
Lead, wt. %.......	1.8,1.5	1.5	1.1,1.5	1.4	2.2
Vac. dist., °F @ 10mm absolute					
5-10%............	430-452	402-448	430-460	465-485	455-468
20-30.............	470-483	480-497	483-503	503-524	496-509
40-50.............	495-506	517-537	523-538	544-565	520-535
60-70.............	520-535	558-586	560-586	588-618	553-566
80-90.............	550-?	624-?	622-?	653-?	580-?
Cracked @, °F.....	558	648	652	686	590

Table 2. ASSAY OF CRANKCASE DRAIN OILS FROM API[1]

	Mobil burning tests Staten Is.,NY	Exxon burning tests Sewell's Point,VA	Shell burning tests Wood River,ILL	Gulf burning tests Gulf R&D Co.
Flash point, °F..	215	350-400	175	218
Vis. @ 100°F, SSU............	248	268	148.3	256
Vis. @ 210°F, SSU............	56.4	....	60.1	....
Viscosity index..	166	....	....	....
Gravity, °API....	24.6	26.0	27.3	25.0
Ash..............	1.81	1.80	1.02	2.41
Water, vol. %....	4.4	....	2.8	....
BS&W, vol. %.....	0.6	....	3.8	....
Sulfur, wt. %....	0.34	....	0.29	0.21
Metals, wt. %				
Lead...........	1.11	0.90	0.72	....
Zinc...........	0.08	0.07	0.035	....
Barium.........	0.06	0.10	0.01	....
Calcium........	0.17	0.10	0.15	....
Phosphorous....	0.09	0.11	0.055	....
Iron...........	0.036	0.02	0.009	....

ably reflect accidental contamination in holding tanks. Gasoline dilution of the crankcase oil, usually in the range of 1-10%, lowers the flash point of the drain oil to about 200-400°F, though lower values are sometimes encountered.

Sediment and ash in the drain oil reflect oil additive residues, carbonaceous and metallic fines, and also gasoline additive residues, the most notable being lead and other metallic compounds, but including bromides and chlorides introduced as scavengers. Lead contents of 0.5 to over 2% are commonly reported, but this is expected to decrease as leaded gasolines sales decline.

Additives are present in the original lubricating oils in concentrations ranging from 0 to about 20%. A typical blend is shown in Table 3. The wide variety of potential additives is indicated in Appendix B. The organic portion of these additives may be susceptible to losses, combustion, and reactions such as occur with the lube oil. However, the inorganics concentrate in the crankcase as oil losses occur and makeup is added. As judged by the typically high viscosity index of drain oil (usually greater than 90), and topped drain oil, a significant amount of the polyisobutylene and polymethacrylate additives remains relatively unchanged.

The oxygen and nitrogen contents of the oils reflect not only additives but also products formed by the reaction of blowby engine combustion gases with the lubricating oil at engine temperatures. These reaction products tend to be unstable, producing color and odor problems, and fouling of equipment during processing.

Most of the automotive service center drain oils are collected by independent collectors and by waste oil processors with collection systems. For example, a study in the state of Massachusetts reports that 88% of service station waste oil is collected, ranging from 95% to the metropolitan Boston area to less than 70% in rural communities.[2] About 88% of car dealer and garage waste oil was also collected, but only about 60% of fleet operator waste oils was estimated as being collected. Our own studies in the Pittsburgh area were consistent with the Massachusetts results. Neither area has an operating re-refiner. Our collector survey showed that the collected drain oils are disposed of as follows:

Re-refining to make lubricating oils

Processing to prepare fuel oils

TABLE 3. TYPICAL GASOLINE ENGINE LUBRICATING OIL INGREDIENT COST (1969)

INGREDIENT	%	COMPONENT COST $/GAL.	COST ¢/GAL.LUBE
1. Base Oil (Solvent 150 Neutral)	86	0.20	17.2
2. Detergent Inhibitor (ZDDP-zinc dialkyl dithiophosphates)	1	2.60	2.6
3. Detergent (barium and calcium sulfonates)	4	2.00	8.0
4. Multi-functional Additive (dispersant, pour-depressant, VI improver-polymethylmethacrylates)	4	2.00	8.0
5. VI Improver (polyisobutylene)	5	0.72	3.6
	100		39.4

Processing to prepare process oils such as asphalt flux oil, form oil, and other oils

Direct use as a fuel by blending with other fuels

Road oils

Dust and weed control oils

Little, if any, collected oil is now being disposed of directly to dumps, wells, or surface waters, though some processing wastes and much of the uncollected oil is disposed of in these ways.

THE DO-IT-YOURSELF MARKET

Considerable lubricating oil is purchased in retail stores by the individual automobile owner both for makeup and changing purposes. The quantity purchased has been estimated to be 168 million gallons per year, with 106 million gallons of waste oil generated (Tables F-7 and F-8). Allowing for 37 million gallons per year of drain oil returned to service stations, 69 million gallons per year are disposed of onto the ground, into garbage cans (most of which ends up in the ground), into storm sewers, into toilets and sinks, etc.

The composition of drain oil in the do-it-yourself market should be similar to that reported for automotive service centers, except that the small amounts of transmission oil, gear oil, etc. may not appear.

COMMERCIAL ENGINE FLEETS

It is estimated that about 200 million gallons per year of lubricating oils are sold to commercial fleets, primarily trucks and construction equipment. Most such vehicles use diesel or gasoline engines.

Diesel engine drain oils are similar to those described previously for gasoline engines, except that lead content is almost negligible. Flash point may be somewhat higher because dilution is by diesel oil rather than the more volatile gasoline.

Very little information is now available on the quantities of waste oil generated by servicing of commercial fleets. Much of the waste oil generated is believed to be used for fuel and dust control. Assuming 50% of sales are generated as waste oil available for collection, about 100 million gallons per year is available for external processing.

The collected oils can be disposed of in the ways already discussed for automotive service centers.

RAILROAD SERVICE CENTERS

Diesel engines are the prime means of locomotion in the railroad industry. Railroad diesel engine lubes are usually isolated from other oils when drained. Much of this oil is shipped to re-refining centers for processing, and returned as usable diesel engine lubricating oil.

Sixty million gallons of railroad diesel lubricating oils are purchased annually. All or almost all of this oil is blended from virgin stocks. We have estimated from interviews with re-refiners that about 5-10 million gallons per year of re-refined oil is returned to the railroads. This recycle quantity was probably much higher in earlier years, but several re-refiners controlled by the railroads or heavily in railroad diesel lube re-refining have been shut down. These figures do not include journal box oils.

Assuming 7 million gallons per year of re-refined railroad diesel lubes at a 70% yield, indicates that about 10 million gallons per year of drain oil was recycled by the railroads. For 60 + 7 = 67 million gallons per year of oil used and 63% recovery, 42 million gallons per year of railroad diesel oil is drained, with 10 million gallons to re-refining and 32 million gallons disposed of in other ways. The possibilities are:

Internal use as fuel

Internal use for dust control

Internal use for non-critical lubricating
purposes, perhaps journal boxes

Sale for the above purposes

Dumping

As with commercial fleets, little information is available on the composition of railroad diesel drain oils. Compositions are expected to be similar to those reported here for automotive oils, except lead content will be negligible and flash point may average a bit higher. It should be understood that elemental analysis of the ash will vary from oil to oil depending upon the exact nature of the oil and fuel additive packages, and the type of metal surfaces encountered in the engine.

AVIATION SERVICE CENTERS

The aviation industry, including both commercial and private aviation, is an important user of petroleum-based fuels and lubricants. Fueling is performed primarily at airports; servicing is performed both at airports and at central maintenance centers.

Major Commercial Airports

Waste oil generation at major airports is likely to include the following:

- jet fuel drained from aircraft. This is a very minor quantity which finds its way to fuel usage.
- aircraft sumping, i.e., water removal from sumps. This becomes a minor constituent in the airport wastewater system.
- loading facility spills. These occur but are not predictable. Some oil may be picked up, but oil is also flushed to sewers.
- draining of petroleum based engine and transmission lubricants, primarily from ground support equipment. These are generally stored and picked up by a collector.
- synthetic lubricants (e.g., phosphate ester base). These are filtered and reused as long as they meet specific gravity, viscosity, acid number, and water specifications. When not reusable, the synthetic lubricants are returned to the manufacturer for reclaiming.
- aircraft exterior and ground support equipment washing. Mixtures of dirt, oil, detergent, and water discharged to wastewater system.
- deicing fluids, e.g., ethylene glycol. Found in cold weather airports. Generally washed off into storm water sewers.

- other ramp area contaminants, including aircraft and ground vehicle leaks and spills. Generally washed off into storm water sewers.

A significant quantity of waste oils and other compounds do appear in airport wastewater and storm water sewers. These may reach surface waters, depending upon the effectiveness of treatment which is known to be inadequate in many airports, especially with regard to storm waters.

Central Aviation Maintenance Centers

The major portion of waste oily materials associated with commercial airlines are generated at central service centers, e.g. the Delta Jet Maintenance Base at the Atlanta, Georgia International Airport,[3] the TWA overhaul base in Kansas.[4] These service centers have comprehensive treating facilities which include segregated oily waste treatment. The oily wastes come from engine overhaul, airframe overhaul, testing, and ground support equipment. Included in this waste are oils, paints, paint strippers, solvents, degreasers, washdown waters, plating wastes, etc. Some oil is separated easily; other oil is emulsified and difficult to separate.

Private Airports

Little is known about oil disposal in the many private airports in the U. S. However, it may be assumed that some airports utilize waste oil storage and collection, while others, because of their very nature, practice dust and weed control or dumping.

The quantities of industrial type waste oil generated are covered in our estimates for other categories. An additional quantity of petroleum base waste oil from the 8 million gallons per year sold as airplane lubricants should be added to these estimates; probably not more than 4 million gallons per year. These have compositions similar to previously described lubricating oils.

THE METAL INDUSTRY

Many types of lubricating and cutting oils, ranging from 100% oil to low concentrations of oil in water emulsions are used in metalworking for lubrication of moving parts and for fabrication or working of metals. Oily materials are added to various points in operations to help shape or form metals, to cool both tools and the metal worked, and to lubricate machinery. Typical operations are rolling, drawing, extrusion, and machining.

As an example, in cold rolling, the steel is usually oiled as it leaves the last wash after pickling. This reduces rusting and acts as a lubricant in the first-stand reduction. Additional fluids, usually emulsions of oils, fats, and/or fatty acids in water, are applied in subsequent reductions to cool the rolls or lubricate the strip and, sometimes, the roll bearings. Oil rates of several thousand gallons per minute may be used. Recirculation of the rolling oil emulsion through a treatment plant is practiced, but losses occur, ending up in wastewater; and the recirculated lubricant must also be drained and changed periodically as impurities, such as suspended solids, build up and degradation occurs.

Recovery of oil from the "soluble" oil emulsion is much more difficult than the recovery of ordinary uncompounded lubricating oils. This is true, first, because the emulsion must be broken with the aid of chemicals, and second, because soluble oils often contain ingredients such as fatty oils (e.g. lard, tallow, rapeseed, castor, sperm), and compounds formed by chlorination and sulfurization, in addition to other additives. The oil may be diluted to 5:100 parts of water, but occasionally to even 1:100 parts of water. The sulfurized/chlorinated oils are particularly useful for heavy-duty or extreme pressure applications such as pipe threading, automatic screw machines, and heavy duty drilling.

In large metal fabricating plants, even where extensive recycling is practiced, relatively large quantities of waste oil are generated. The waste oils may be segregated, for example after draining hydraulic or lubricating systems, but more often the oils are all released to a wastewater treatment plant. Here, a major portion of the oils are usually recovered in a concentrated but contaminated form by skimming, while the remaining oils enter the environment by disposal of sludges or flocs separated from the water before or after treatment, or as suspended oil remaining in the treated wastewater stream. Relatively large quantities of oil also appear with scale, shavings, and other solid wastes.

Based on very limited data from Maryland,[5] it has been estimated that perhaps 100 million gallons of waste oil is generated nationally for possible recycle or alternative uses out of 150 million gallons per year sold as metal-working oils. Much of this oil is incinerated, and some is reprocessed for fuel and other uses.[5]

PROCESS OIL CONSUMERS

The process oil consumers by definition do not generate large quantities of waste oil, since most of the oil becomes an integral part of the product produced. For example, process oils made from lube stocks for rubber, ink, textiles, and agricultural sprays, and other uses totaled more than 300 million gallons in 1970. Forty to fifty percent of this quantity was consumed in the rubber industry for plasticization, reinforcement, and extension.[6] Each process use has its own specifications, but many require oils similar to lube stocks. Some other process oils, defined by the U. S. Census Bureau as having a viscosity of more than 45 Saybolt seconds at 100°F, include[7]:

Absorbent oils
Apron dressings
Belt dressings
Brick oils
Cable oils
Coal spray oils
Cordage oils
Defoamants
Flotation oils
Farm oils and compounds
Fruit and vegetable preservatives
Launching grease base and slip coats
Paint and putty oils
Paper processing oils
Petroleum sulfonates
Polishing oils
Rust preventative oils and compounds
Tanners products
White oils

Spillage and other losses are the only normal sources of waste oil from most of the process oils. However, a few process oils, such as flotation oils, do require discard, generating waste oils.

No data are presently available, but a reasonable estimate based on our analysis of a survey in Maryland[5] is that 5-15% of process oils result in waste oil generation. Of course, it should be recognized that process oils do enter the environment directly in a variety of ways; for example, as a liquid when using agricultural sprays for weed control, evaporation from inks, and disposal of waste rubber products by incineration.

OTHER INDUSTRIAL OILS (Lubricating and Non-Lubricating)

Included in this general category for purposes of this report are all industrial oils, other than those mentioned in the preceding sections, which have as their source lubricating oil stocks sold to industry. These include:

Turbine oils
Gas engine oils
Transformer oils
Refrigeration oils
Heat transfer oils
Hydraulic oils

The total in this category sold to industry is close to 600 million gallons per year including 325 million gallons hydraulic and circulating system oils (refrigeration, heat transfer, other). Additional breakdown, where available, is given in Tables F-9 and F-10. Internal recycling is practiced by some companies for some of these oils; for example, transformer, turbine, and hydraulic oils. Others, such as gas engine oils, become waste oils when drained. In any case, even where internal recycling is practiced, a major portion of the oils purchased eventually leaves its industrial use as waste oil. Estimates for waste oil generated are also given in Tables F-9 and F-10.

Most of the waste oils available have compositions similar to the original product but with impurities such as fine suspended dust and metal particles, and oxidation and decomposition products. However, waste oil picked up from industrial plants may be mixtures of oil types, and may be contaminated with synthetic oils, solvents, polychlorinated heat transfer and transformer oils, etc.

Some industrial oil wastes are re-refined and sold or returned to the original user, i.e., in a closed loop system. Others are internally disposed of, e.g. as fuel, by incineration, or for alternative non-critical uses, such as oiling belt conveyors and dust control.

MARINE TRANSPORTATION WASTE OILS

Huge quantities of crude petroleum and refined products are transported by tanker, barge, and pipeline into and out of refineries and terminals in the U. S. Included are about 60 billion gallons per year imported (1971), over 3 billion gallons exported, and even larger quantities moving in coastal, lake, canal, and river commerce. This transportation results in waste oil generation from spills, bilge and ballast waters, and tanker washing. Each of these are discussed briefly below. Further detail on the quantities involved are presented in **Tables F-4 and F-5.**

Oil Spills

Marine oil spills obviously can vary greatly from year to year. Even one major tanker mishap can affect such statistics. However, normal spillage along the U. S. Coast accounts for only a small fraction of the total waste oil generated. For example, spills in 1972 are believed to have been on the order of 20 million gallons. Waste oil actually recovered from these spills would be even smaller, probably less than 5 million gallons.

The composition of the waste oil obviously depends primarily upon the nature of the product, ranging from crude oil to gasoline. Lighter fractions, such as gasoline, if spilled, would evaporate and not be recovered as waste oil. Composition of the waste oil recovered also depends upon the nature of the waterway, the type of recovery used, and materials added to aid in recovery or dispersion. For example, recovered liquids can be very high in salt water content, and can even contain materials such as straw used to aid in recovery.

Some oils recovered from spills have been disposed of by landfill. Incineration and processing to product useful fuels are other disposal possibilities, but facilities which can handle recovered oils without producing polluting air or water emissions are usually not available where needed.

Ballast Wastewater

Water used as ballast must be discharged from tanker oil storage tanks at oil distribution terminals or at sea before taking on a fresh load. This wastewater contains from 0.1 to 2% oil.[8] Assuming an average of 1.25% oil, 145 million gallons per year of waste oil is potentially available from an estimated 11.6 billion gallons per year of ballast water, most of which is still dumped at sea.

Proper ballast wastewater treatment, where practiced, consists of a separator to recover the bulk of the free oil, followed by other methods such as air flotation and biological treatment. Onshore ballast treatment makes 90-95% of the ballast wastewater oil available as contaminated oil for subsequent processing to fuel or other uses.

Bilge Wastewater

Wastewater collected in a ship's bilge will often be contaminated by concentrations of oil similar to that in ballast wastewater. Assuming an average of 1% oil, 11 million gallons per year of waste oil is potentially available from an estimated 1.1 billion gallons per year of bilge wastewater.[8]

This water can be treated similarly to ballast wastewater, or mixed with the ballast wastewater for common treatment.

Tanker Washings

Tanker and barge washing is important, especially when changing products to be transported. Assuming an average of 10% oil,[9] 31 million gallons per year of oil is potentially available from an estimated 313 million gallons per year of tanker washings.[8] Washing is sometimes done at sea, at the oil terminal, or at independent facilities. Here too, oil recovery and water disposal is similar to that described for ballast wastewater.

INDUSTRIAL PROCESS WASTE OILS

The waste oils considered here are those which emanate from industrial processes such as petroleum refining, petrochemicals, meat processing, vegetable oil production, wool processing, and coke manufacture. Unlike many of the waste oils discussed earlier, the quantities of process waste oils are not readily estimated from sales, since they represent waste products generated during processing.

Petroleum Industry

Refining crude oil and producing petrochemicals may result in losses from about 0.1 to 2% of the total processed.[10] Modern well operated refineries are expected to keep these losses to under 0.5%. This consists of contaminated waste oil; tank cleaning residues; evaporation; losses to discharged process, cooling and runoff water; and losses to liquid and solid wastes, including water treatment sludge and floc, and acid and caustic sludges. Refineries do practice recycle of waste oils, using "slop" storage tanks and sometimes special rerun towers for oil recovery. The quantities involved are normally well under 1% of refinery throughput, perhaps as little as 0.1%. The largest single source of oil actually lost in refineries is evaporation from tanks, valves, flanges, and the like. This quantity may reach or exceed 0.4%.

However, in addition to losses in the refinery itself, considerable additional losses may occur during production on land and offshore, during overland and inland transportation (e.g., pipelines, trucks, barges), during transfers and storage at terminals and bulk plants, during conversion to petrochemicals, and during storage and use by the ultimate fuel users. Data obtained from various companies engaged in the petroleum industry and from petroleum users make it seem likely that 0.5% of petroleum liquids or more, excluding refinery evaporative losses, are effectively lost to the industry and to users. Based on 1971 statistics shown in Table F-2, this amounts to 1156 million gallons per year.

Spills of volatile hydrocarbons, such as gasoline fractions, land spills, discharge of wastewaters, and oil-containing sludge disposal results in almost complete unavailability of lost oil for recycle. However, tank cleaning, recovery from wastewater in oil/water separators, and other loss modes do result in a major portion of the estimated loss being available for recycle.

Although firm data is not available, an estimate of 50% of oil lost directly to the environment via wastewater, disposal of liquids and sludges on the land and in deep wells, and evaporation outside of the refinery appears reasonable. The balance then, 578 million gallons per year, is theoretically recoverable waste oil. Some of this is recovered and used for fuel and road oil, some is incinerated, and some may be disposed of in other ways. The composition obviously depends on the source and history of the waste oil.

Oil and Fat Industry

Fats and oils may be classified as vegetable oils, animal fats and oils, and fish oils. These are mixtures of the glycerides of various fatty acids. Some vegetable and animal waxes, which are mixed fatty acid esters of polyhydric alcohols other than glycerol, might also be included in this discussion. The distinction between fats and oils is merely melting point, oils being liquids at or near ordinary ambient temperatures. Fatty acids in oils are more unsaturated than in fats.

About 24 billion pounds per year of fats and oils were produced in the U. S. in 1969.[11] Vegetable oils are recovered by expression or solvent extraction followed by extensive refining. Animal fats and oils and fish oils are recovered by rendering and other cooking processes followed by centrifugation and other separation and purification steps. Vegetable oil yields range from about 5-60% depending on the source, for example about 15-18% from cottonseed and soybeans, 34% yield of linseed oil from flaxseed, and 45-50% from shelled peanuts.[12] Fish oil yield is on the order of 20%.[12] The residual meals or cakes, usually containing some oil, are commonly used for animal feed, and in some instances for human consumption, fertilizers, and industrial uses. Many important byproducts are recovered during fat and oil production.

The most important uses are in foods, soaps, paint, varnish, and resins. Other important uses for fats and oils and their derivatives are lubrication and hydraulic oils, medicinal oils, plasticizers, wetting agents, and detergents. Waxes are used for polishes, candles, electrical insulation, waterproofing, phonograph records, and a variety of other uses.

Almost all of the fats and oils produced are consumed, finally appearing in the environment as human waste, soaps in water, and coatings on solid waste. However, as with petroleum, the production, transportation, and use of fats and oils and their raw materials and oily products do produce oily wastes, usually as a low concentration contamination in wastewaters. About 1% of the total fats and oils are recovered as "waste" materials and sold for use in noncritical applications, for example soap manufacture, at a price of 3-15 cents per pound, depending on quality. Another 0.5% may be lost with wastewaters and wastewater sludges, incinerated, collected with other solid wastes for disposal, or collected from retail establishments, such as restaurants, by tallow collectors. This 0.5% amounts to about 13 million gallons per year.

Coking Ovens

Another important source of oils is the coking, or pyrolysis, of coals. The coke is used in blast furnaces for pig iron production and for other metallurgical purposes. Coking, as usually practiced in the U. S., yields about 2-4 gallons of light oil and 8-12 gallons of coal tar per ton of coal. Based on 90 million tons of coking coal, about 270 million gallons of light oil and 900 million gallons of coal tar are produced in this way. The coal tar is usually distilled to produce additional light oil, heavier oils, and pitch. Each of the oil products can be further processed to produce valuable products such as benzene, toluene, xylenes, pyridines, phenols, creosols, naphthalenes, anthracenes, and fuel oils.[12]

Some of the oils appear in steel plant wastewaters. Others appear as wastes, as with petroleum, in transportation and usage. If 0.5% waste oil is generated here also, this would produce about 6 million gallons per year of waste oil.

SYNTHETIC OILS

Although still a small industry, increasing amounts of synthetic oil are manufactured and used for special lubrication problems, for example, very low temperatures, very high temperatures, and other severe services, such as jet aircraft. Some of the synthetic oils in use are polymers of olefinic hydrocarbons (e.g. polyisobutylene VI improver), polyalkylene glycols and perfluorinated polyalkylene glycols, synthetic esters (e.g. phosphate and dibasic acid esters), silicone oils, halogenated hydrocarbons, and polyphenyl ethers.[13]

Waste synthetic oils should be segregated and recycled where possible, because of their high cost, and because they may contaminate otherwise recyclable oils. This has already been discussed with respect to use in aircraft. Some synthetic oil manufacturers do accept synthetic waste oils for reprocessing.

SECTION V

RECYCLE AND DISPOSAL TECHNIQUES FOR VEHICULAR WASTE OILS

The recycling of crankcase drain oils has reached a critical juncture. On one hand, increasing pressure which would lead to the use of every available combustible material as fuel is everywhere evident. On the other hand, the desire to conserve natural resources and the environment requires that every consideration be given to the possibilities of re-refining drain oil to lube oil base stocks.

For many years a group of 150 or more small businessmen, called re-refiners, provided a means for recycling substantial amounts of crankcase drain oil and other waste lubricating oils back to the public and to industry in the form of bulk or packaged lubricating oils. This group has now shrunk to less than 40, leaving behind the question as to the ultimate destinations of the oil which used to be re-refined. Some of these destinations are discussed elsewhere in the report. They include road oiling and dust control which leads to runoff and land and water pollution; use as a low sulfur fuel, which leads to contaminant metal particulate emissions to the air (largely lead from crankcase oils) and heat exchanger tube fouling; and dumping.

The reasons for the decline of the re-refining industry have been thoroughly discussed elsewhere.[14] The problems are complex and manifold, related to taxes, labeling regulations, fewer oil changes, increased use of oil additives, some government specifications which prohibit recycled oil, competition from fuel and road oiling dealers, and outdated technology.

The following discussion deals primarily with the problem of technology and current re-refining processes, which produce waste products difficult and expensive to dispose of according to the rigorous standards which are being imposed today.

CURRENT PROCESSES FOR RE-REFINING LUBE OILS

A summary of 35 waste oil recycling operations is presented in Table 4. The data is based on visits with 30 companies and other information obtained by telephone. A list of re-refining companies is presented as Appendix A.

Table 4. SURVEY OF WASTE OIL RE-REFINERS

XX = MAJOR
X = MINOR

COMPANY	PROCESS			PRODUCT CAPACITY, GPD		SOURCES OF FEED				PRODUCTS		COMMENT
	ACID	CLAY*	OTHER	DESIGN	OPERATING	CRANKCASE OIL	RR DIESEL	INDUSTRIAL OILS	OTHER	LUBE & TRANSMISSION OILS	OTHER	
1.		x	--	10,000	7,000	xx	--	--	--	xx	Fuel oil (10%)	
2.	x	x	--	25,000	10,000	xx	--	x	--	xx	Gear oil, compressor oil	Experimenting with acid sludge lime mixture for disposal as powdered sludge
3.	x	x	--	24,000	12,000	xx	--	--	--	xx	Penetrating oils	
4.	x	x		20,000	8,000	xx (70%)	x (20%)	x	--	x	Journal box oil	Propane extraction (inactive)
5.	x	x	--	25,000	20,000	xx			All types of waste oils	xx	--	
6.	--	x	Caustic soda/ silicate	--	6,500	xx	x			xx	--	
7.	--	x	Pre-treatment of feed & distillation	40,000	25,000	xx	--	x	--	xx	--	

Table 4. SURVEY OF WASTE OIL RE-REFINERS (Continued)

XX = MAJOR
X = MINOR

COMPANY	PROCESS			PRODUCT CAPACITY, GPD		SOURCES OF FEED				PRODUCTS		COMMENTS
	ACID	CLAY*	OTHER	DESIGN	OPERATING	CRANKCASE OIL	RR DIESEL	INDUSTRIAL OILS	OTHER	LUBE & TRANSMISSION OILS	OTHER	
8.	x	x	--	8,300	5,200	xx	--	x	--	xx	Industrial oil (60%)	1.5 mm gal. storage capacity
9.	x	x	Caustic pre-treatment	2,500	1,800	xx	--	--	--	xx	--	
10.	--	--	--	45-90,000 25,000	20-30,000 (fuel) 2,000 (lube oil)	x	--	xx	animal oils	x (10%)	Fuel (90%)	Planning to stop lube oil processing
11.	--	x	--	--	2,000	xx	--	--	--	xx	Hydraulic oil, machinery lubricants	Plans 25% expansion
12.	--	--	Not specified	8,300	8,300	xx	--	--	--	xx	Fuel (minor)	2,000,000 gal storage capacity
13.	--	x	Multistage continuous distn.	26,000	12,000	xx	--	xx	--	xx	Industrial oils, transmission oils machinery lubricants	
14.	x	x	--	--	12,000	x	--	--	--	x	Asphalt flux oil	Planning modernization

Table 4. SURVEY OF WASTE OIL RE-REFINERS (Continued)

XX = MAJOR
x = MINOR

COMPANY	PROCESS			PRODUCT CAPACITY, GPD		SOURCES OF FEED				PRODUCTS		COMMENTS
	ACID	CLAY*	OTHER	DESIGN	OPERATING	CRANKCASE OIL	RR DIESEL	INDUSTRIAL OILS	OTHER	LUBE & TRANSMISSION OILS	OTHER	
15.	x	x	--	48,000	40,000	x	x	--	--	xx	Journal box hydraulic, gear oils	Planning modernization
16.	x	x	Continuous	--	2,000	x	--	x	--	x	Hydraulic, fuel, spray form oils	Trying to sell out
17.	x	x	De-emulsif. of indust. oil	22,000	22,000	x	--	x	Soluble & cutting oils	xx	Road, hydraulic oils.	Some custom industrial work
18.	x	x	--	8,000	8,000	x	--	x	Watered fuels, transformer oils	xx	Fuel, asphalt blending oil	Planning to rotary vac. filter odor from water problem
19.	x	x	Dewater & filter indust. oils	25,000	25,000	x	--	Cutting & other indust. oils hydraulic oil	--	xx	Industrial oils	Expanding capacity-considerable custom indus. work - had had polychlorinated biphenyl problem-acid sludge neutralized before disposal

Table 4. SURVEY OF WASTE OIL RE-REFINERS (Continued)

XX = MAJOR
X = MINOR

COMPANY	PROCESS			PRODUCT CAPACITY, GPD		SOURCES OF NEED				PRODUCTS		COMMENTS
	ACID	CLAY*	OTHER	DESIGN	OPERATING	CRANKCASE OIL	RR DIESEL	INDUSTRIAL OILS	OTHER	LUBE & TRANSMISSION OILS	OTHER	
20.	x	x	--	--	6,000	x	--	--	--	xx	Transmission oil, form & spray oil (little processing)	Trying to sell out
21.	x	x	--	9,000	8,000	x	x	--	--	xx	Journal box oil, diesel lubes	No longer has site for acid sludge disposal-may go to dehydration only to make fuel.
22.	--	--	Distillation	30,000	--	x	--	x	Contaminated fuels	x	Fuel	None
23.	x	x	--	2,500	2,500	x	--	--	--	xx	Form oil	
24.	x	x	Caustic	6,000	4,000	x	--	--	--	xx	--	
25.	x	x	--	4,000	4,000	x	--	--	--	xx	--	
26.	x	x	--	2,000	2,000	x	--	--	--	xx		
27.	--	--	Distillation	--	--	x	x	x	Jet fuels, interface fuels	--	Fuels, asphalt flux	New re-refining process under devel. Customers segregate oils.

Table 4. SURVEY OF WASTE OIL RE-REFINERS (Continued)

COMPANY	PROCESS			CAPACITY, GPD		SOURCES OF FEED XX=MAJOR X=MINOR				PRODUCTS		COMMENTS
	ACID	CLAY *	OTHER	DESIGN	OPERATING	CRANKCASE OIL	RR DIESEL	INDUSTRIAL OILS	OTHER	LUBE & TRANSMISSION OILS	OTHER	
28.	x	x	--	10,000	4,000	x	--	x	--	xx	--	
29.	--	x	--	15,000	6,000	x	--	x	Cutting and cooling oils	--	Journal oil, industrial oils	Formerly did railroad bus. custom indus. work major business
30.	x	x	--	6,000	6,000	x	--	--	--	xx	Hydraulic oil	
31.	x	x	--	7,500		x	--	x	--	--	Fuel Journal box oil	
32.	x	x	--	--	12,500	x	--	x	--	xx	Chain oil, chemical carrier	
33.	-	x	Distillation	25,000	5,000	x	--	--	--	--	Sweeping compound	
34.	x	x	--	2,400	1,900	x	--	--	Waste diesel fuel		Transformer oil	
35.	x	x	--	20,000	--	x	x	x	Solvents	x	Journal box oil, diesel lube	

* Normally includes an oil stripping step.

As can be seen from Table 4, the acid/clay treatment process has dominated the re-refining industry. Of the 27 companies producing lube stocks, 24 use acid/clay treatment. A few use distillation/clay treating which,has been developed as an alternative. Following is a discussion of these two processes. A detailed discussion of waste products produced during processing is provided in Section VIII.

Acid/Clay Treatment

A process scheme for a typical acid/clay re-refining of waste automotive oils is shown in Figure 1. The process for diesel engine waste oils differs only in process condition details.

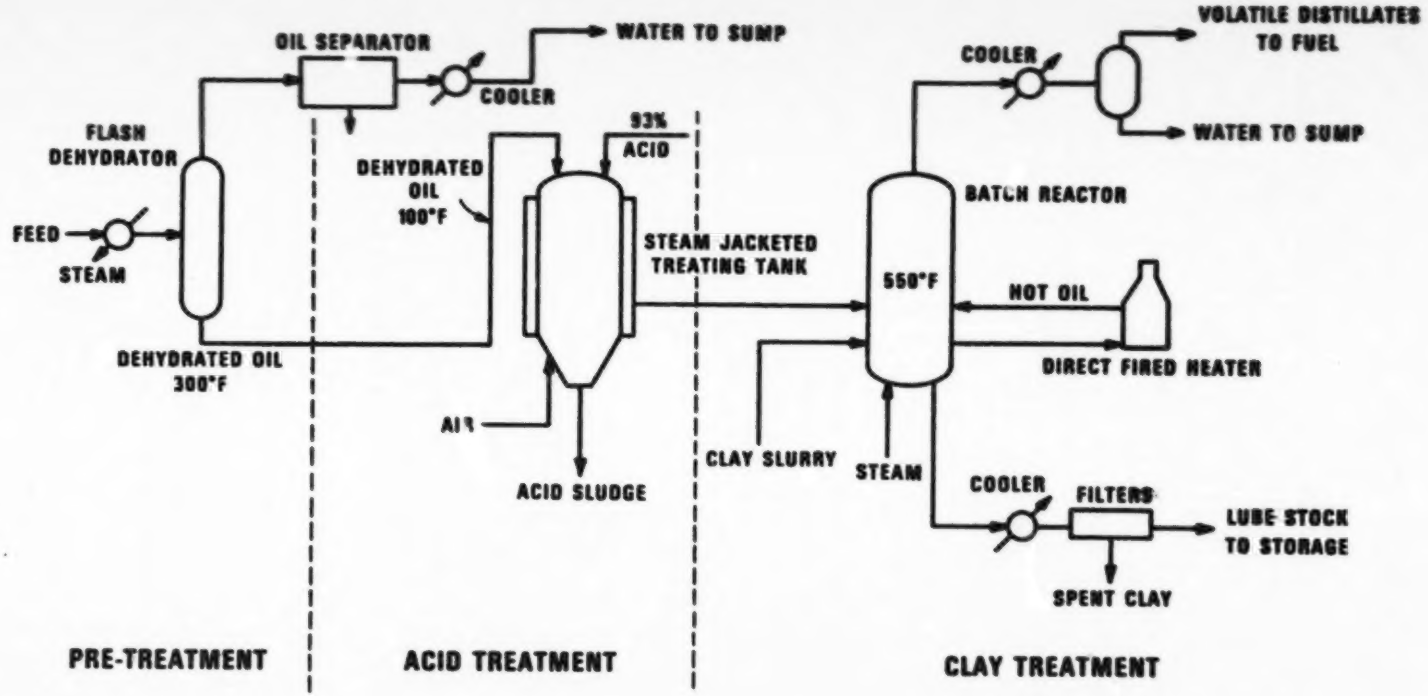
Incoming materials are unloaded into a partially submerged tank directly from the collection trucks. This receiving tank must be fitted with grids and screens to remove the debris which is normally found in the waste materials. The recommended tank would be large enough to accept the entire truck load and permit any free water to settle. The oil is then decanted and transferred to feed storage tanks. The water layer is pumped to a skimmer and then to wastewater disposal. The proper handling of the raw material is extremely important to a smoothly operating facility.

Based on data obtained from re-refiners, it is believed that a typical analysis of oil in the storage tanks would be

Water	3.5% by volume
Naphtha	7.0% by volume
Oil, etc.	89.5% by volume

More detailed analyses were presented in Tables 1 and 2. The feed is pumped through a steam heat exchanger to the flash dehydrator which operates at 300°F and atmospheric pressure. The steam/oil overhead is condensed and separated; the oil to light end storage to be used for fuel, and the water to the wastewater disposal system.

The dehydrated oil is sometimes further stripped of light fractions prior to acid treating, but more often it is pumped directly to dry oil tanks, where it is stored and cooled. It can be stored for 2 to 4 days before it picks up appreciable moisture, which tends to increase acid requirements during the following step. After 48 hours


OIL SEPARATOR
WATER TO SUMP
COOLER
FLASH DEHYDRATOR
FEED
STEAM
DEHYDRATED OIL 300°F
DEHYDRATED OIL 100°F
93% ACID
STEAM JACKETED TREATING TANK
AIR
ACID SLUDGE
COOLER
VOLATILE DISTILLATES TO FUEL
WATER TO SUMP
BATCH REACTOR
550°F
HOT OIL
DIRECT FIRED HEATER
CLAY SLURRY
STEAM
COOLER
FILTERS
LUBE STOCK TO STORAGE
SPENT CLAY
PRE-TREATMENT
ACID TREATMENT
CLAY TREATMENT

RE-REFINING BY AN ACID/CLAY PROCESS

FIGURE 1

storage the oil temperature has dropped to approximately 100°F.

Dry oil is pumped to one of several acid treating units. These units are steam jacketed and are agitated with plant air. Four to six volume percent of 93% sulfuric acid is added to the reactor where the temperature is maintained at about 100°F. Although fresh acid is usually used, several re-refiners use spent alkylation acid from petroleum refineries. The oxidized products contained in the oil are usually removed from the oil by the acid within 24 hours, but up to 48 hours may be required depending on the raw material. The acid sludge, containing oil contaminants and ash, separates from the oil and is drawn off from the reactor bottom. Acid sludge analyses are presented in Section VIII. Acid sludge disposal, usually done in landfills or lagoons, is one of the most critical problems in this process.

The acid-treated dehydrated oil is then transferred to the steam stripping-clay treating operations. The clay treater consists of a slurry tank, a tower, a condenser, and a direct fired heater through which the oil is circulated. The capacity of the clay treater is usually on the order of 5000 to 10,000 gallons. It is equipped with a sparger for direct introduction of steam.

After the batch has been transferred to the clay treating tower, the temperature is brought up to 550-600°F by circulating through the heater, and live steam is introduced. The purpose of the stripping operation is to remove the remaining light fuel fractions and odorous compounds which may be present. The steam-stripped materials are condensed, and the oil separated from the water. The water fraction is treated through the wastewater disposal system, and the oil fraction used as plant fuel.

The heat is discontinued after 12-15 hours and part of the oil is diverted to the clay slurry tank. The oil temperature is permitted to drop to approximately 400°F. The clay, often a 50% mixture of activated clay and diatomaceous earth (200-250 mesh), is mixed into the circulating oil. The clay dose is approximately 0.4 pounds per gallon of oil. The clay removes color bodies and colloidal carbon by adsorption.

The hot oil (250-350°F) containing the clay is filtered through a plate and frame filter press, sometimes followed by a second filter in series. The clarified oil is then stored either prior to or after having the necessary additives blended into the stock.

The filter cake, a mixture of clay, impurities, and oil, is uneconomical to separate and recover after filtration in small plants. It must therefore be discarded, usually by landfill. Paper, which is often used as a fulter medium in the plate and flame press, is discarded with the cake.

Odors can be a problem with acid/clay re-refining. These may emanate from storage tanks, processing vessels, wastewater treatment facilities, acid sludge, and oil spills. In some re-refining operations, odors can be controlled adequately by sealing open vessels and tanks, good housekeeping, and by venting process vessels to furnaces where vapors are burned with the normal fuel. Other plants have resorted to control methods such as caustic scrubbers to treat gases vented from the treating steps.

The wastewater system varies from plant to plant, depending on cooling water and vacuum facilities, water runoff problems, land availability, water contamination of feedstocks, governmental regulations, and availability of a local sewage plant. A typical installation includes an API separator with oil skimming, pH control, some water recycle, and discharge to a sewage plant. Sewage plants will normally accept water with oil contents up to about 100 ppm, a quality level relatively easy to meet.

Overall lube stock yields of 45-75% have been reported for acid/clay treatment. These obviously depend upon operating conditions and feed composition, with water sludge, ash, and gasoline contents being most critical. For the feed reported here (3.5% H_2O, 7.0% naphtha), greater than 70% yield is believed to be possible with careful operation, but a typical yield might be closer to 60-65%.

The oil produced by the acid/clay process can be considered a solvent neutral blending stock having an SUS (Saybolt Universal Second) viscosity generally between 55 and 58 at 210°F. This is equivalent to an SAE 20 oil. The lube stock can be blended to a finished lube by the re-refiner or sold directly to a jobber with blending facilities. For SAE 30 oil, the viscosity is increased to 58-70 SUS (usually 60-65) at 210°F by the addition of virgin bright stocks, or by the addition of polyisobutylene.

The viscosity index of re-refined oil normally exceeds

90, even without additional additives. However, conventional additive packages are used for high viscosity index requirements and for high performance specifications. Additional data and discussion of oil properties and specifications are available.[14,15]

Distillation/Clay Treatment

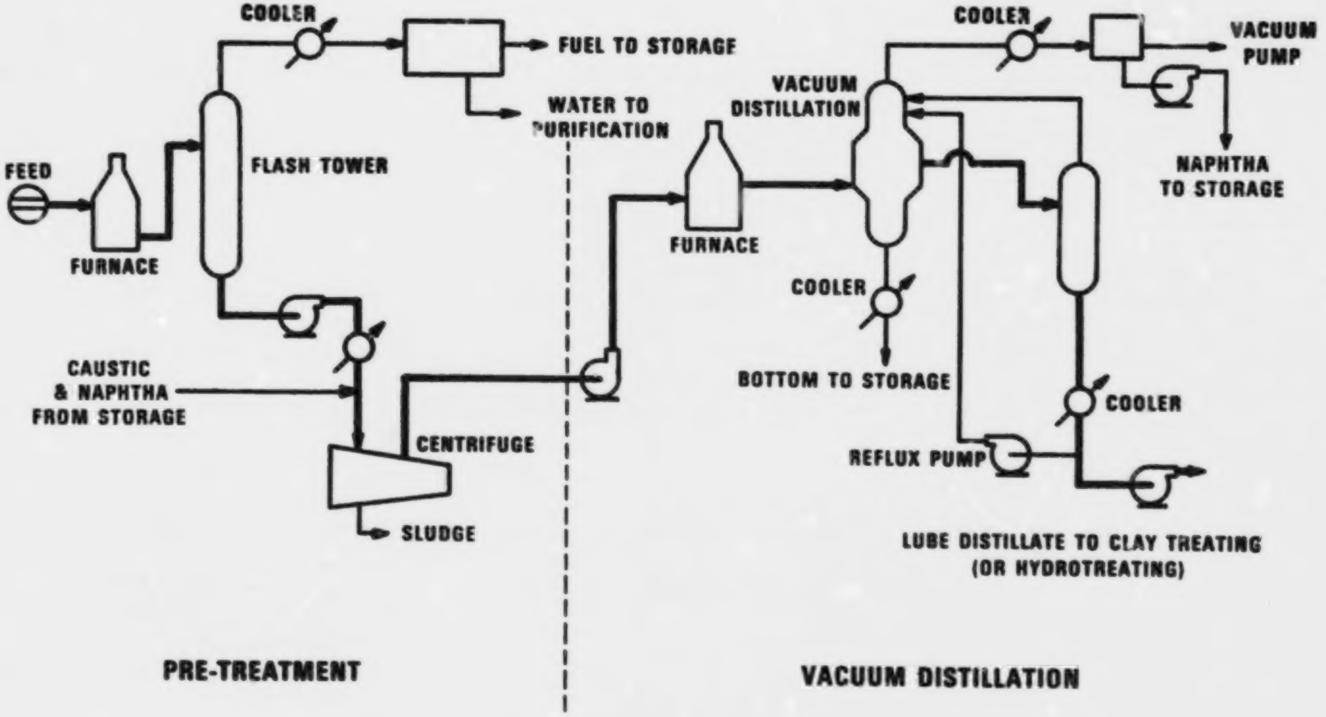
The distillation/clay process overcomes the serious acid sludge waste disposal problem connected with acid/clay treatment. The following description is based partly on work supported by EPA[16] and partly on patent literature.[17,18] The pretreatment and distillation steps are shown in Figure 2.

The waste oils are received at the plant in the usual manner previously described. The oil is dehydrated in a flash tower by heating to 300°F in a direct heater, using as fuel light fractions generated during processing. The flash tower operates at atmospheric pressure and 300°F. The oil/water overhead is condensed and sent on to an oil decanter. The water phase is separated and removed to the wastewater disposal system. The oil layer is used as fuel.

The flash tower bottoms are passed through a heat exchanger to reduce the temperature to approximately 100°F. Light oil, having a boiling range of 150-250°F is introduced into the dehydrated oil stream. The quantity used is approximately 20% based on oil volume. A small amount of caustic, 0.2-2.0%, dependent on feedstock emulsions, is also introduced. The addition of the light oil and caustic tends to break the oil-water emulsion and precipitate solids. These materials are removed by centrifugation. The sludge from the centrifuge can be disposed of separately, e.g. by landfill, or it can be mixed with the distillate bottoms as described later.

The naphtha/caustic/centrifuge pretreatment step may not be a necessary adjunct to distillation, but it does tend to eliminate some of the materials which can cause fouling and erosion in the vacuum distillation furnace and column, and associated heat exchangers.

The centrifuged oil is then pumped to the vacuum distillation tower through a direct fired heater. The furnace heats the oil to about 700°F. The columns operates at a vacuum of 27 inches of mercury. The overhead naphtha, with a boiling range as shown in Table 5, is condensed, cooled, and used as fuel in the plant.


COOLER
FUEL TO STORAGE
WATER TO PURIFICATION
FEED
FURNACE
FLASH TOWER
CAUSTIC & NAPHTHA FROM STORAGE
CENTRIFUGE
SLUDGE
COOLER
VACUUM DISTILLATION
VACUUM PUMP
NAPHTHA TO STORAGE
FURNACE
COOLER
BOTTOM TO STORAGE
COOLER
REFLUX PUMP
LUBE DISTILLATE TO CLAY TREATING (OR HYDROTREATING)
PRE-TREATMENT
VACUUM DISTILLATION

VACUUM DISTILLATION OF CRANKCASE WASTE OIL

FIGURE 2

Table 5. PHYSICAL PROPERTIES OF
VACUUM DISTILLATION FRACTIONS[16]*

Fraction	Name	Amount, % of Feed	Color	Viscosity SSU	Boiling Range $^{\circ}$F	Specific Gravity	Flash Pt. (Open Cup) $^{\circ}$F
1	Naphtha	1.5			145-446	0.7972 46° API	
2	Barometric	9	4 1/2	33-34@ 100°F	400-680	0.8602 33° API	
3	Light Side-stream	36	8	100 @ 100°F 39.1 @ 210°F	680-792	0.8735 30.5° API	350
4	Heavy Side-stream	28	8	222 @ 100°F 47.6 @ 210°F	792-900	0.8789 29.5° API	430
5	Bottoms	22	dark	284 Sayb. Furol @ 122°F	900+	0.9937 10.9° API	
Residue, Water + Loss		3.5				1.0 10° API	
		Total 100%				Av. S.G. of Feed Stock 0.9035 25.1° API	

* No pretreatment

The bottoms, which contain almost the entire ash content of the feed, are cooled and used as fuel, for blending into asphaltic products, or stored in a lagoon. One or more middle distillate cuts are taken (Table 5) and sent to clay treatment for finishing as a lube blending stock.

The clay treatment is similar to that described for the acid/clay process except that prior stripping is unnecessary and the clay quantity may be reduced to as little as 0.125 lbs. per gallon of oil. The filter cake obtained during filtration is disposed of in the usual manner.

The yields for this type operation, based on input oil, are approximately 70%, comparable to the best acid/clay treating operations. Product quality should also be comparable, although viscosity at 210°F seems to be somewhat lower due to bottoms removal.

By taking more than one side-stream from the vacuum distillation column, it may be possible to obtain a part of the yield as higher viscosity lube stocks. The properties of some distilled motor oils are shown in Tables 5 and 6. It is believed that clay treatment leaves most of these properties relatively unchanged, except for improvements in color, neutralization number, and reductions in oxygen and nitrogen content.

Odor and wastewater problems are not believed to be any more serious with this process than with acid/clay treatment. However, when a barometric condenser is used for the vacuum column, the quantity of contaminated wastewater is very large. Water or air-cooled surface condensers are preferable to barometric condensers, but are more expensive, though the increased cost must be balanced against the decreased cost of wastewater treatment.

POTENTIAL PROCESSES FOR RE-REFINING LUBE OILS

At least two processes are available for re-refining of crankcase drain oils that are not now in use in the U. S. These are: a solvent extraction process followed by treatment with reduced amounts of acid and clay as compared to the conventional process; and a vacuum distillation process followed by catalytic hydrogen treating instead of clay treating as discussed earlier.

Table 6. PROPERTIES OF DISTILLED USED MOTOR OILS[1]

	Texas(B)	Texas(A)	California	New York
Yields:				
Overhead, vol.%........	0-77	3.5-89.9*	0-82.9+	0-89.9*
wt. %........	73.5	85.2	79.1	85.7
Bottoms, wt. %.........	26.5	14.8	21.9	14.3
DISTILLATE:				
Vis. @ 100°F, SSU......	151	197.9	188.8	144
Vis. @ 210°F, SSU......	43.6	46.5	46.0	43.1
Viscosity index........	104	105	105	105
Color, ASTM............	3.5	7.5	8.0	Lt. 7.0
Neut. Number...........	.....	0.38	0.59	0.23
Polar compounds, wt. %				
Sulfur...............	0.09	0.12	0.13	0.12
Oxygen...............	0.19	0.17	0.35	0.16
Nitrogen.............	0.04	0.03	0.02	0.02
Boiling range, °F......	380-1050	530-1010	472-1022	462-1006

*0-3.5 volume fraction of water and light hydrocarbons was collected overhead, separate from oil product.

+Heat treated while purging with nitrogen for 24 hours at 270°F to drive off water prior to distillation.

Solvent Extraction/Acid/Clay Treatment

The solvent extraction/acid/clay process is a relatively new development in the re-refining of waste lubricating oils. It has been tried experimentally in the U. S., but no plants are now in operation. A 9-million-gallon-per-year plant is operating in Italy based on a process developed by Institut Francais du Petrole (IFP).[19]

The basis for the process is the use of propane to selectively extract the base lube stock from the additives and impurities. The propane, containing dissolved oil, is removed from the extractor, while the high boiling, dark colored asphaltic and oxidized hydrocarbons and suspended solids are removed from the unit bottom as a residue. The bottoms are mixed with a fuel oil and used as plant fuel, or otherwise disposed of; whereas the propane is flashed from the oil and recycled.

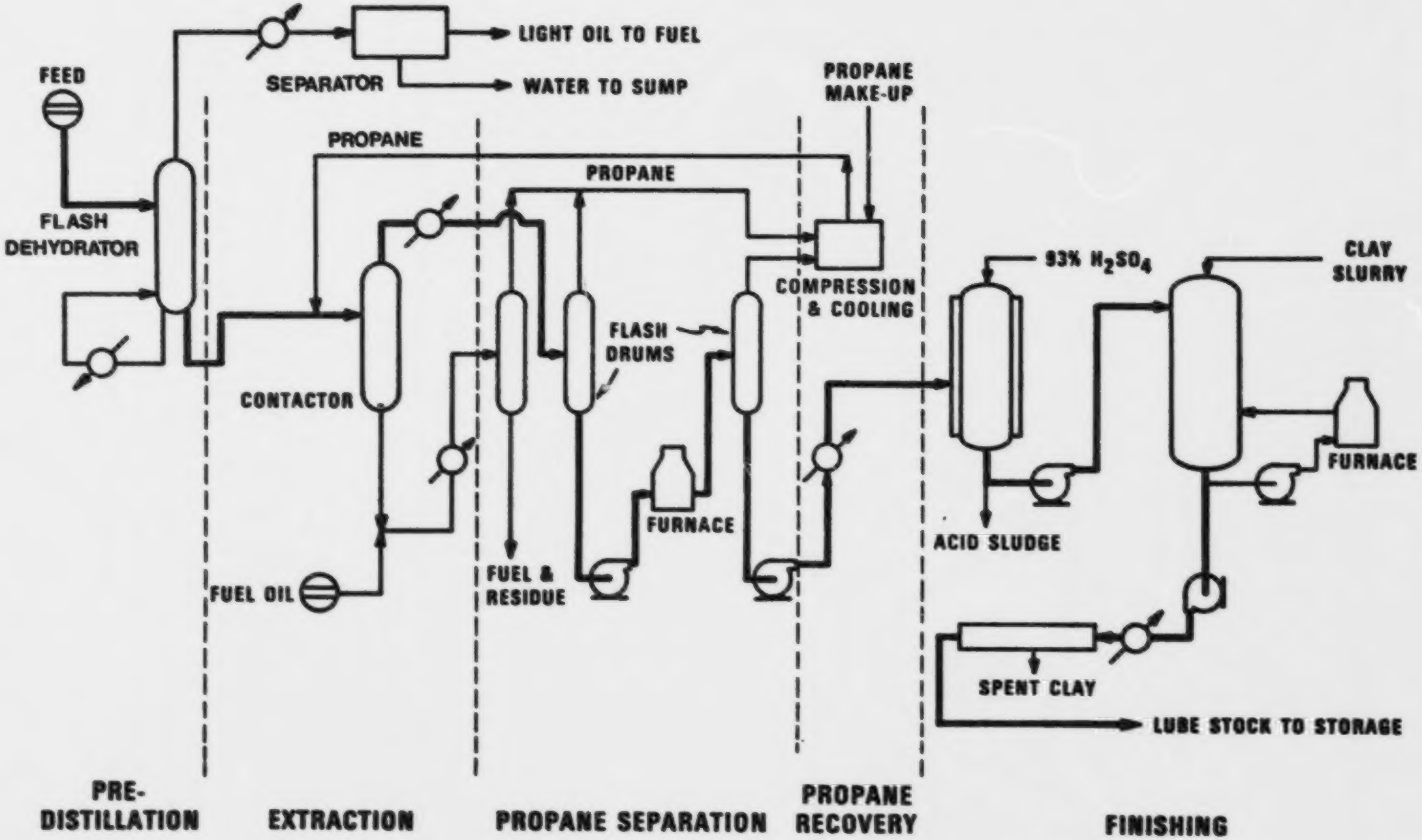
The process scheme, as shown in Figure 3, consists of the following:

a. Thermal dehydration
b. Precipitation and solvent extraction
c. Propane recovery
d. Acid treatment
e. Clay treatment and filtration

The incoming waste oil is unloaded into a receiving tank as described before. The feed for the process is pumped through the steam heat exchanger to the flash dehydrator, operated at about 300°F and atmospheric pressure. The overhead is condensed and drained into an oil separator. The water layer is disposed of through the wastewater disposal system; the oil layer is either stored or processed immediately in the solvent extractor.

The oil is pumped to the precipitation tower (solvent extractor) via a heat exchanger. The propane is also heated and introduced into the tower approximately 1/3 up from the bottom. The oil is introduced 1/3 down from the top. The solvent extractor operates at several hundred pounds per square inch pressure. The propane-oil solution (the oil having dissolved in solvent) goes overhead due to specific gravity differences, whereas the precipitate flows to the extractor (contactor) bottom.

The counter-current flow is important to efficient extraction. Steam coils, installed at the tower top and


FEED
FLASH DEHYDRATOR
SEPARATOR
LIGHT OIL TO FUEL
WATER TO SUMP
PROPANE
PROPANE
PROPANE MAKE-UP
COMPRESSION & COOLING
CONTACTOR
FUEL OIL
FUEL & RESIDUE
FLASH DRUMS
FURNACE
93% H_2SO_4
CLAY SLURRY
FURNACE
ACID SLUDGE
SPENT CLAY
LUBE STOCK TO STORAGE
PRE-DISTILLATION
EXTRACTION
PROPANE SEPARATION
PROPANE RECOVERY
FINISHING

RE-REFINING BY A PROPANE EXTRACTION PROCESS

FIGURE 3

bottom, control the temperature at the desired level in the 100-200°F range.

For very high quality lube oil, the solvent-to-feed ratio would be approximately 20:1. This will vary and must be determined for each feedstock. The lowest solvent-to-feed ratio would be 1:1, yielding poor quality oil in the raffinate. Current operations are believed to be in the vicinity of 15:1.

A small amount of the fuel oil is added to assist in the flow of the high viscosity residue from the unit. The residue is released from the extractor by a liquid level controller. The fuel oil-residue mixture is stored for use as fuel for the direct fired heaters, or for other means of disposal.

The propane-oil solution is flashed through a pressure reducing valve into a solvent flash drum. It is usual to use a two-stage flash to separate the propane and oil. The propane gas is then liquefied and recycled.

The lube oil is sent on to acid/clay treatment as described in the acid/clay process. The solvent extraction process requires only about 2% of 93% sulfuric acid by volume based on oil, compared with 4-6% for the acid/clay process. After treatment with about 0.15 lbs. of clay per gallon at 300°F and filtration, the lube oil quality is reported to be superior to the acid/clay product, at least in terms of color and color stability, and perhaps viscosity.[19]

Although the quantities of acid and clay required in the IFP process are greatly reduced, a disposal problem still exists. No acid sludge analysis is available, but the metals content, e.g. lead, is undoubtedly lower than for the acid/clay process. Most of the metals and other impurities appear in the fuel oil-residue mixture. Therefore, the use of this material as a fuel is environmentally questionable, unless accompanied by a considerable investment in air pollution control equipment.

Boiler tube fouling which will also occur due to the ash content, also detracts from the use of the fuel oil-residue mixture in normal applications.

Distillation/Hydrogen Treatment

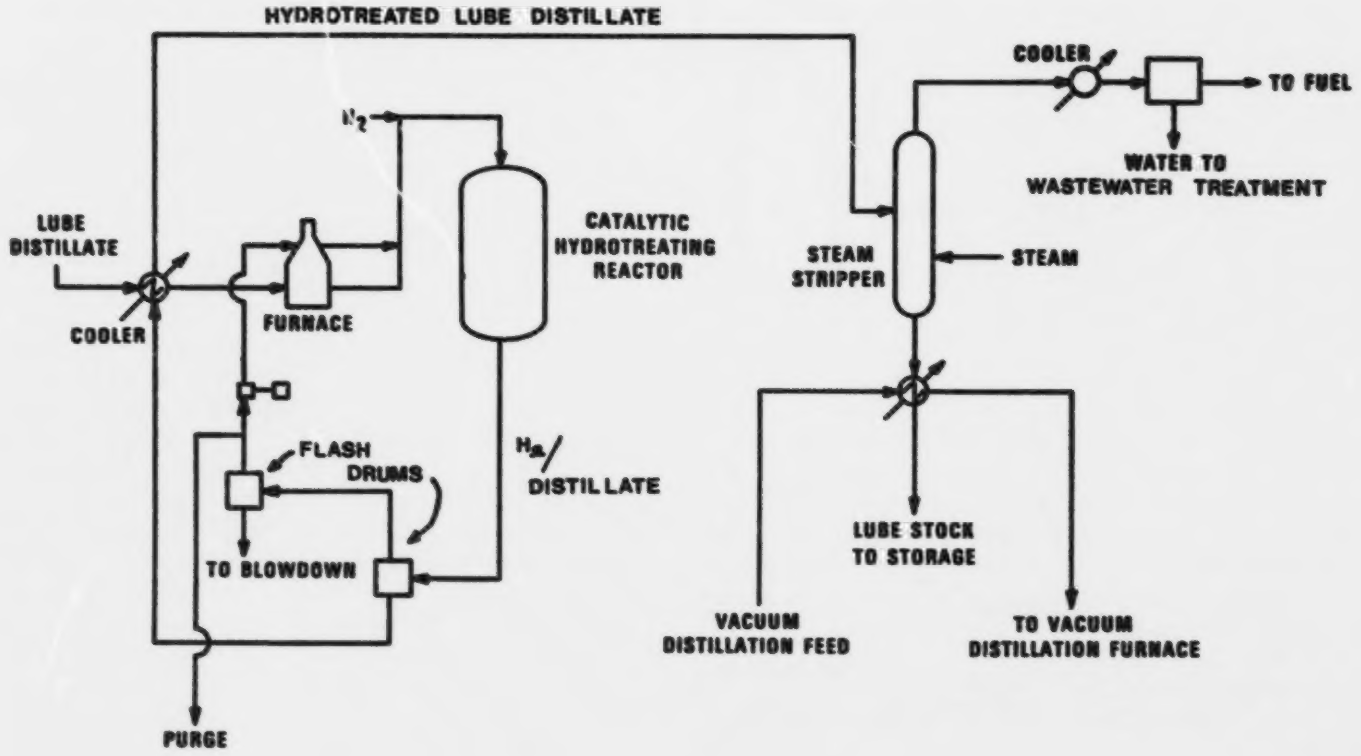
The distillation/hydrogen treating process is similar to distillation/clay treating, except for the finishing step, shown in Figure 4. Although this scheme is widely used in petroleum refineries, no plants are now operating on waste oils. However, two European installations to be started up in the period 1974-76 are apparently planning to combine hydrogen treating with the IFP propane extraction process previously described.[20]

As described before, a pretreat section can be used ahead of vacuum distillation to reduce fouling and erosion problems. The distillate (sidestream) from the vacuum distillation column is heated using hydrotreating product and an oil fired heater before being mixed with recycle and makeup hydrogen. The hydrogen-oil mixture is contacted with a standard commercial hydrotreating catalyst in a fixed bed. The hydrogen reacts with oxygen and nitrogen-containing impurities and unsaturates.

The pressure is reduced in two flash drums in series and the recovered gaseous hydrogen is recycled. The purified oil is used to preheat the incoming feed and then injected into a vacuum or stream stripping column where the small amount of volatile materials which may have formed is removed. The purified product leaving the stripper can be used to preheat vacuum distillation feed before final cooling and storage.

Recent work, summarized in Table 7, has shown that the hydrogen treated distillate can match typical properties of 150 vis neutral lube blending stock. Hydrotreating conditions used in this work were 650 psig., 650°F, 800 standard cubic feet of hydrogen recycled per barrel of feed, and a space velocity of 1.0 v/v/hr (volumes of feed per hour per volume of catalyst).

The distillation bottoms which contain almost all of the objectionable impurities can be disposed of as discussed before. However, work is now underway, under an EPA grant, for use of this high lead material (from automotive crankcase waste oil) as a fuel in a secondary lead smelting operation. If this is successful as expected, the distillation/hydrogen treating scheme holds promise as being the first re-refining process available without a solid waste disposal problem.


HYDROTREATED LUBE DISTILLATE
N_2
LUBE DISTILLATE
COOLER
FURNACE
CATALYTIC HYDROTREATING REACTOR
FLASH DRUMS
TO BLOWDOWN
H_2/ DISTILLATE
PURGE
STEAM STRIPPER
STEAM
COOLER
TO FUEL
WATER TO WASTEWATER TREATMENT
LUBE STOCK TO STORAGE
VACUUM DISTILLATION FEED
TO VACUUM DISTILLATION FURNACE

HYDROTREATING

FIGURE 4

Table 7. DISTILLATION AND HYDROGEN TREATMENT OF USED MOTOR OIL[1]

	Used* motor oil	Used+ oil distillate	Distilled-Hydrofined oil 650 psig., 1 V/V, 800 scf/b H_2			Typical properties of 150 vis neutral lube base stock
			550°F	600°F	650°F	
Vis. @ 100°F, SSU...	237	164	162	159	156	157
Vis. @ 210°F, SSU...	55.4	44.3	44.1	44.1	43.8	43.0
Viscosity index.....	166‡	102	101	104	103	104
Color, ASTM........	Black	Black	Lt. 1.5	Lt. 1.0	Lt. 1.5	1.5
Color stability,TR.. (16 hrs @ 212°F)	.....	.....	18	16	17	.....
Gravity, °API @ 60°F..............	26.0	30.7	31.3	31.4	31.5	31.8
Flash, COC,°F.......	200	440	420	430	410	415
Pour point, °F......	-30	+15	+20	+20	+15	+15
Neutralization No...	5.87	0.51	0.0	0.0	0.0	0.01
Con. carbon, wt. %..	3.33	0.01	0.001	0.001	0.001	0.01
Copper strip corr... (3 hrs @ 212°F)	.....	.....	2	2	1	1
Sulfur, wt. %.......	0.30	0.12	0.053	0.031	0.012	0.08
Nitrogen, wt. %.....	0.08	0.018	0.006	0.006	0.002	.....

*Used crankcase oil from a 30,000-gallon tank at the Sewell's Point terminal (4/2/70).

+650-945°F cut (14-90 vol. %).

‡The light materials in used motor oil obscure the determination of the VI of the base oil.

As for other environmental problems, the wastewater problem is similar to other re-refining processes and can be overcome by conventional design. A scrubber may be required to remove impurities from the hydrogen purge stream and other minor gaseous discharges.

Additional work on catalyst life and hydrogen consumption would be desirable before commercialization of this process.

Other Re-Refining Approaches

Many proposals for alternative re-refining processes have centered about the possibility of using solvents and/ or chemical treating agents. None of these approaches is in use for producing lubricating oils, although some claims are made as to the efficacy of caustic,[21] isopropanol[22], and butanol treatments.[23]

The use of several chemical flocculants and solvent precipitants such as aluminum chloride, triethanolamine, and trichloroethylene were studied by Armour Research Foundation about 1960, but they showed little promise at the conditions used.[24] Walter C. McCrone Associates in 1971 investigated a number of non-acid flocculents as alternatives to sulfuric acid for treating drain oils.[25] Alkanolamines and a diglycolamine were found to be the most effective. These research programs were supported by the Association of Petroleum Re-refiners.

More recently, National Oil Recovery Corporation (NORCO) under sponsorship of the U. S. Environmental Protection Agency, has investigated a number of materials for waste oil treatment, some of which hold some promise as being economically effective re-refining agents. A report on the NORCO work should be available in 1974.

Some of the above and other potential re-refining approaches have been described in a recent state-of-the-art report.[15]

EVALUATION OF WASTE LUBE OIL DISPOSAL TECHNOLOGY

An economic comparison has been made of the re-refining schemes previously discussed. Re-refining to lube stocks has also been compared with the cost of distillation to prepare a clean fuel oil, and combustion in boilers for steam production as alternative methods for using crankcase waste oils. Other waste lubricating oils and disposal methods are considered.

Cost Basis

The cost basis chosen is meant to provide:

1. comparisons of various re-refining technologies.
2. comparison of re-refining with other environmentally acceptable methods of using crankcase waste oils.
3. a measure of the attractiveness of new re-refining facilities to produce lubricating oils from crankcase waste oil not now being recycled.

The size of new re-refining facilities should be as large as possible for efficient operation, but oil collection costs, which increase with collection area, provides a major restraint on plant size.

A grass roots acid/clay plant accepting 5 million gallons per year of crankcase waste oil (or drain oil), as will be seen, is about a minimum economic size, resulting in close to break-even operation. All comparisons were made for this size operation. At the 5 million gallon per year size, as many as 80 new facilities could be built to handle the estimated 400 million gallons per year of drain oil not now being recycled (excluding industrial lube oils).

Operation was assumed to be 24 hours per day, 5 days per week, 50 weeks per year. This type of operation allows repair and maintenance on weekends as necessary, while minimizing the complexity of manning, and providing flexibility for increasing plant capacity when necessary. It is the type of operation now most common in this industry. Costs might be reduced somewhat by continuous 7-day-per-week operation with shutdowns as required for repair and maintenance.

The costs (mid-1973 basis) presented are general and meant for orientation purposes only. They are based on process design calculations, but not detailed mechanical designs. Other cost bases are included in Tables 11 and 12.

Process Comparisons

The costs for the various alternatives have been summarized in Table 8. Costs for the acid/clay process are about 3 to 5¢/gal. of lube product higher than for the alternative re-refining schemes, which were essentially a standoff within the accuracy of this comparison. A new German/Israeli development described in Section VII reduces acid consumption and cost in the acid/clay process.

The distillation/hydrotreating alternative has the advantage of producing no waste products, but the process has not yet been demonstrated on a commercial scale for drain oils. Available experimental data is promising.[26]

The propane extraction process, followed by acid/clay treatment at lower levels than ordinarily used, is offered in the U. S. by IFP, a French company.[19] A plant based on this process is now operating in Italy. Pilot plant work on a similar process has also been conducted in the U. S.[27] The disadvantage of propane extraction is that, although acid and clay waste are reduced, they are not eliminated. The process also produces a high ash fuel oil which will cause tube fouling problems when burned in ordinary combustion equipment, as has been experienced in the Italian plant cited.[20]

The distillation/clay process economics are based in part on patent descriptions.[17,18] It is believed that two re-refiners in the U. S. operate plants at least similar to these descriptions. The process eliminates acid sludge, but spent clay disposal remains as a problem, though much less serious. In addition, a sludge is produced during pretreatment, if carried out according to the referenced patent, and a high ash bottoms product results from the distillation step, as is true in all the processes which involve the distillation step. The disposal of the bottoms and solids residues was discussed earlier.

The production of clean fuels by distillation does not appear attractive, as compared to the preparation of lubes, unless fuel prices increase significantly relative to lubes.

TABLE 8. SUMMARY OF CRANKCASE WASTE OIL PROCESSES

Process	Primary Product	Primary Wastes & Byproducts	Grass Roots Econ.-5 Million Gal/Yr. Investment	 Op. Cost*	Comments
Acid/Clay	Lube blending stock	Acid sludge, spent clay	$1,153,000	21.9¢/Gal. Lube	Widely used in U. S.
Extraction/ Acid/Clay	Lube blending stock	Acid sludge, spent clay; high ash fuel byproduct	$1,363,000	18.4¢/Gal. Lube	One operating plant in Italy.
Distillation/ Clay	Lube blending stock	Spent clay; high ash fuel byproduct	$1,173,000	17.3¢/Gal. Lube	At least two plants in U.S.
Distillation/ H_2 Treating	Lube blending stock	High ash fuel byproduct	$1,342,000	19.0¢/Gal. Lube	Under development.
Distillation	Fuel oil (diesel fraction could possibly be recovered)	High ash fuel byproduct	$ 930,000	14.6¢/Gal. Fuel oil	Can make high quality fuel, but economics questionable.
Controlled Combustion	Steam	Ash concentrate	$ 492,000	80¢/1000 Lbs. Steam	Speculative-fine particle recovery difficult.

* Includes 3¢/gal. feed cost and 10%/yr. depreciation, but excludes return on investment. See Tables 9,10, and 11 for details.

TABLE 9. CRANKCASE WASTE OIL PROCESSING CAPITAL INVESTMENT

Basis: 5 Million Gal/Yr. Raw Oil; 250 Days/Yr. Operation

Process Product	Acid/Clay Lube	Extr/Acid/Clay Lube	Dist/Clay Lube	Dist/H_2 Lube	Dist. Fuel	Comb. Steam
Investment, $1000						
Process Equip.	662	829	609	773	423	200
Storage Facil.	367	402	440	440	400	200
Office & Lab.	32	32	32	32	32	32
	1061	1263	1081	1245	855	432
Land & Site Improvement	92	100	92	97	75	60
	1153	1363	1173	1342	930	492

TABLE 10. POTENTIAL PROFITABILITY OF CRANKCASE WASTE OIL PROCESSES

Basis: 5 Million Gal/Yr. Raw Oil; 250 Days/Yr. Operation

Process	Acid/Clay	Extr./Acid/Clay	Dist./Clay	Dist./H_2	Dist.	Incin.
Product	Lube Oil	Lube Oil	Lube Oil	Lube Oil	Fuel Oil	Steam
Investment, $1000	1153	1363	1173	1342	930	492
Oper. Costs (Excl. Feed) Per Unit of Product	17.76¢/Gal.	14.86¢/Gal.	13.38¢/Gal.	15.02¢/Gal.	10.67¢/Gal.	50.54¢/1000 Lbs.
Feed Costs @ 3¢/Gal. Of Raw Oil	4.17	3.57	3.95	3.95	3.95	29.35
Total Costs	21.93¢/Gal.	18.43¢/Gal.	17.33¢/Gal.	18.97¢/Gal.	14.62¢/Gal.	79.89¢/1000 Lbs.
Product Credits						
Lube Stock @ 22¢/Gal.	22.00	22.00	22.00	22.00	-	-
Fuel Oil @ 15¢/Gal.	-	-	-	-	15.00	-
Steam @ $1.50/1000 Lbs.	-	-	-	-	-	150.00
High Ash Fuel Oil @ 8¢/Gal.	-	0.59	0.55	0.55	0.55	-
	22.00¢/Gal. Lube	22.59¢/Gal. Lube	22.55¢/Gal. Lube	22.55¢/Gal. Lube	15.55¢/Gal. Fuel Oil	150.00¢/1000 Lbs. Steam
Profit (Before Tax)						
Per Unit Product	0.07¢/Gal.	4.16¢/Gal.	5.22¢/Gal.	3.58¢/Gal.	0.93¢/Gal.	70.11¢/1000 Lbs.
$/Yr.	2,500	174,700	198,400	136,000	35,400	358,000
%/Yr. Return	0.2	12.8	16.9	10.1	3.8	72.8
Return, %/Yr. Before Tax						
Lube Stock @ 22¢/Gal.	0.2	12.8	16.9	10.1	-	-
Lube Stock @ 25¢/Gal.	9.6	22.1	26.6	18.6	-	-
Lube Stock @ 30¢/Gal.	25.6	37.5	42.8	32.8	-	-

TABLE 11. CRANKCASE WASTE OIL PROCESS OPERATING COSTS

Basis: 5 Million Gal/Yr. Raw Oil; 250 Days/Yr. Operation

Process	**Acid/Clay**		**Extr./Acid/Clay**		**Dist./Clay**		**Dist./H_2**		**Dist.**		**Incin.**	
Product - Type	Lube Oil		Lube Oil		Lube Oil		Lube Oil		Fuel Oil		Steam	
- Yearly Prod.	3.6 x 10^6 Gal.		4.2 x 10^6 Gal.		3.8 x 10^6 Gal.		3.8 x 10^6 Gal.		3.8 x 10^6 Gal.		511 x 10^6 Lbs. (85,200 Lbs./Hr.)	
Lube Yield												
Investment, $1000												
Plant (P)	1061		1263		1081		1245		855		432	
Land & Site	92		100		92		97		75		60	
	1153		1363		1173		1342		930		492	
Chemicals	Basis*	¢/Gal.	Basis*	¢/Gal.	Basis*	¢/Gal.	Basis*	¢/Gal.	Basis*	¢/Gal.	Basis*	¢/1000 lb.
93% H_2SO_4 @ 3¢/Lb.	1.06	3.18	0.36	1.08	-	-	-	-	-	-	-	-
Clay @ 3.3¢/Lb.	0.4	1.32	0.15	0.50	.125	0.41	-	-	-	-	-	-
H_2 @ 0.4¢/SCF	-	-	-	-	-	-	3.6	1.44	-	-	-	-
Propane @ 2¢/Lb.	-	-	0.03	0.06	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	0.40	-	0.26	-	0.40	-	-
Utilities												
Elec. Power @ 3¢/KWH	0.1	0.30	0.3	0.90	0.2	0.60	0.2	0.60	0.15	0.45	2.35	7.05
Water @ 5¢/1000 Gal.	0.017	0.09	0.04	0.20	0.021	0.11	0.02	0.10	0.02	0.10	0.3	1.50
No. 6 Fuel Oil @ 12¢/Gal.	-	-	0.037	0.44	-	-	-	-	-	-	-	-
Plant Labor												
Wages @ $11,000/Yr.	8 men	2.44	8 men	2.10	8 men	2.32	8 men	2.32	7 men	2.03	5 men	10.76
Supplies & OH @ 50%	-	1.22	-	1.05	-	1.16	-	1.16	-	1.01	-	5.38
Maintenance	5%P/Yr.	.1.47	5%P/Yr.	1.50	5%P/Yr.	1.42	5%P/Yr.	1.64	5%P/Yr.	1.13	6%P/Yr.	4.24
Ins. & Local Taxes @ 3% Invest./Yr.	-	0.96	-	0.97	-	0.93	-	1.06	-	0.73	-	2.89
Waste Disposal	-	0.50	-	0.20	-	0.03	-	-	-	-	-	-
Depreciation @ 10% P/Yr.	-	2.95	-	3.01	-	2.84	-	3.28	-	2.25	-	8.45
Indirect Costs												
Salaries	$80,000 Per Yr.	2.22	$80,000 Per Yr.	1.90	$80,000 Per Yr.	2.11	$80,000 Per Yr.	2.11	$65,000 Per Yr.	1.71	$35,000 Per Yr.	6.85
Suppl.& OH @ 50%	-	1.11	-	0.95	-	1.05	-	1.05	-	0.86	-	3.42
Oper. Cost (Excl.Feed)		17.76 ¢/Gal. Lube		14.86 ¢/Gal. Lube		13.38 ¢/Gal. Lube		15.02 ¢/Gal. Lube		10.67 ¢/Gal. Fuel Oil		50.54 ¢/1000 Lbs Steam

* Per unit of product.

The possibility of taking a light fraction of this material as diesel fuel is under study.[23]

Where a market for steam exists, it appears that a combustion system with well designed air pollution control equipment could be attractive. If scrubbers are used, for example high energy venturis with 100 inches of water pressure drop, a water treatment system for solids recovery must be included.

The economics presented here are for orientation purposes. Each proposed plant must be designed in detail to account for the range in feedstock compositions and quantities expected, the peculiarities of a particular collection system, local problems of waste disposal, etc. The yields assumed are somewhat optimistic, though attainable with some feedstocks and careful operation, but not representative of most existing re-refineries.

An assumption inherent in the economic comparison of the lube producing processes is that product quality is the same for each process. Insufficient data is available to properly examine the validity of this assumption.

Other Disposal Techniques

Uncontrolled combustion (with little or no air pollution control), road oiling, and dust control are commonly used alternatives for waste oil disposal. These uses may return anywhere from 1 to 12¢ per gallon more to the waste oil collector than the 2-7¢ per gallon of raw oil paid by a re-refiner. For example, a collector may take a dust control contract for 10-15¢/gallon, laying down the oil directly from his collection truck.

The re-refiner has a very difficult time competing with such uses for waste lubricating oils on a pure price basis, particularly in times of fuel oil shortage. However, both resource and environmental conservation should be important considerations when contemplating alternative methods for waste oil disposal.

Drain Oil as a Fuel - The uncontrolled use of automotive drain oil as a fuel could result in the discharge of 30-40 million pounds per year of lead, plus other metal containing particulates, to the atmosphere. This is, of course, true whether or not the waste oil has been blended with cleaner fuel to avoid exceeding source and air quality standards and to minimize heat transfer surface fouling. This quantity of lead represents about 3-4% of U. S. mine production in 1969[11] (or about 1% of consumption). Since U. S. lead reserves are limited, some is now imported,[11] good conservation practice dictates against indiscriminate emission of lead.

Lube oil conservation is also an important consideration. Lubes are now in short supply, consumption having caught up with production capacity.[28] The production of lubes, which requires a series of expensive refining steps from specially selected crude oils, is not readily expanded.

Health hazards associated with the accumulation of lead in the body are well known. Although uncontrolled combustion of waste oils contributes much less lead to the atmosphere than is emitted from gasoline combustion in engines, the amount is significant as discussed above. While health and other environmental effects are not fully understood, there is undoubtedly some risk in uncontrolled combustion, a risk increased by the fact that the particle size of the bulk of the emitted particles is likely to be less than one micron.[29] In view of the potential attractiveness of re-refining, this risk does not seem to be worth taking.

If new restrictions on lead in gasoline are maintained, automotive drain oil lead will gradually decrease, but significant levels will persist for many years. Furthermore, pressures to decrease gasoline consumption in automobiles could possibly result in a return to high compression ratio and the renewed need for lead anti-knock compounds.

An unconfirmed report that drain oils have been used as a fuel for drying of hops (used in beer) is another illustration of the need for controls. Many animal and human foodstuffs undergo direct fired drying as a processing step where contamination could result from the unsuspected use of drain oil blended into a clean fuel.

Drain Oil for Road Oiling and Dust Control - A study of run-off of oils from roads treated to suppress dust clearly shows the potential environmental problems which can result.[32] Conservation of lead and lubrication oils, as discussed above, also dictates against this practice. In spite of this and the availability of more suitable oils, over 300 million gallons per year may be used for this purpose (see Section X, Table 26).

Asphalt - Some drain oil and distilled drain oil fractions are used as cutting stocks for asphalt manufacture. Little is known about the environmental effect of such use. Most of the metallic compounds, including lead compounds, present in the oil are relatively insoluble in water and presumably coated with viscous asphaltic materials. Therefore, little rain leaching would be expected for asphalt uses such as roofing and roads.

Form Oil - Drain oil and drain oil fractions are also sold for coating forms used for concrete and other building materials. Presumably this drain oil eventually reaches the environment through disposal of forms to landfill, or burning of wooden forms.

Chemical Raw Materials - Drain oil fractions recovered by the distillation/clay process (bottoms) and other processes are reported to be useful in rubber products.[6] However, raw drain oil cannot be used, so that this application is not a true competitor for re-refining, but rather may be complementary.

Paraffinic materials, such as drain oils, are potentially useful as feedstocks for steam cracking to produce ethylene, propylene, butenes, and butadiene, the most important petrochemicals used in plastics manufacture. The market is so large that it could theoretically use all of the waste automotive and industrial lubricating oils available. However, the presence of ash dictates against the use of raw oils in conventional steam cracking tubular furnaces.

The distilled product from drain oil would probably make a good steam cracker feed, but as has been shown, the cost for producing this product in a 5 million gallon per year plant exceeds fuel price. A careful study of yields and costs is necessary to determine the attractiveness of this approach. The excellent yields of monomers obtained with waxy distillate feed, offset by lower aromatic yields, is an indicator of what might occur with drain oil distillate.[31]

Alternative processes, such as high temperature fluidized bed coking, have been used for cracking crude oil and heavy petroleum to ethylene and other monomers. These might be applied to raw drain oil, but, again, a careful study of yields and costs is required.

Light fractions of the paraffinic lube waste oil distillate could be raw materials for n-paraffin recovery depending on the n-paraffin content, not now known. A large market exists for n-paraffins in the manufacture of straight chain benzene alkylates, an essential component of biodegradable detergents.

Animal feed protein is also made from n-paraffins, with a boiling range of 175-300° C (347-572°F), by fermentation with yeast and appropriate nutrients, producing about one pound of yeast (63-65% protein) per pound of n-paraffin.[32] The pure n-paraffin appears to be the preferred feedstock, but hydrocarbon fractions containing n-paraffins can also be used. This suggests that a light boiling distillate fraction from waste lube oils might be used if the n-paraffin content is sufficiently high. Presumably further purification would be required to remove even traces of lead and other impurities.

Partial oxidation to product carbon monoxide/hydrogen mixtures is another possible application for raw drain oil. Partial oxidation to produce synthesis gas can be an important starting point for many industrially important chemicals, including hydrogen, ammonia, methanol, formaldehyde, and oxo alcohols. The scrubbing system could be designed to remove ash components mixed with fine carbonaceous residues, a normal product of partial oxidation. The effect of ash components on the refractory of the 2200-3000°F partial oxidation reactors would require study.

Petroleum Refinery Raw Material - The paraffinic crankcase waste oils also could be useful as a catalytic cracking or hydrocracking raw material, except that ash components would most likely act as catalyst poisons. The distilled material could be used for catalytic cracking, but the cost would probably make the economics marginal at best. Even the very small lead residue would make its use in hydrocracking dubious from an economic viewpoint. The petroleum industry could undoubtedly handle the problem of waste oils if they were forced to, but their reluctance to do so is understandable.

SECTION VI

RECYCLE AND DISPOSAL TECHNIQUES FOR OTHER WASTE OILS

Waste oils, other than the vehicular waste oils discussed in the previous section, include:

1. industrial lube type oils, including lube oils, hydraulic oils, transformer oils not heavily contaminated, where recycle and disposal techniques and problems are similar to those described for vehicular waste oils, except that lead content may not be a problem.
2. emulsified oils, e.g. metal working, lubricating, and some hydraulic oils where separation from water presents a special problem; and where the possible presence of special impurities such as halides, sulfur, and fatty oils are serious deterrents to recycle.
3. other petroleum-based industrial oils including heavily contaminated lube oils, process oils, oils skimmed from oil/water separators, mixed unsegregated industrial oils, and tank cleanings.
4. waste vegetable, animal, and fish fats and oils.
5. oil/water mixtures from marine sources including spills, ballast, bilge, and tanker washing, a major portion of which is water, often salt water.

INDUSTRIAL LUBE TYPE OILS

As noted above, recycle techniques for industrial lubes are similar to those for drain oils. Several re-refiners provide services to industry whereby segregated waste oil is collected, processed, and returned to the customer in a closed loop. Oils with a high ash content may undergo conventional dehydration and acid/clay treatment, whereas low solids content oils may undergo only dehydration and clay treatment.

Recycling is sometimes done within the industrial plant, with centrifugation to remove metal particles followed by clay treatment as a common approach to the problem. In-plant recycle of transformer oils may involve only vacuum dehydration and filtration. Waste industrial lubricating oils are also used as a fuel, with none of the restraints on the similar use of automotive drain oil caused by lead content, unless contaminated with automotive drain oil.

EMULSIFIED OILS

Where service is not severe and reasonable segregation can be maintained, oil-water emulsions can be recycled, or oil can be recovered from the emulsion, purified, and re-emulsified for re-use. However, in most industrial situations treatment of oil-water emulsions results from oil contamination of waters and has as its primary objective the purification of the wastewater. In such situations, the oil is often disposed of as a high water content floc or sludge, although further concentration to produce a fuel is becoming more common.

As an example of internal recycle, soluble (emulsified) cooling oils used for cold rolling in steel mills is often isolated and recycled. The steps involved may include gravity separation and skimming to remove free oils, filtration to remove solid contaminants, and addition of bactericides, antioxidants, or other agents to extend the life of the soluble cooling oil. However, even this recycled coolant eventually degrades and requires disposal by emulsion breaking.

On the other hand, many plant wastewaters systems are contaminated by lubricants from a multitude of sources, for example, cutting oils, hydraulic oils, oil mist collectors, and coolants. Treatment of these wastewaters ranges from simple separators to sophisticated multi-step treatment systems which includes chemical addition.[33] The following description is a hypothetical example of the steps which can be followed to both recover oil and produce an acceptable water quality for discharge or recycle. Few plants practice all of these steps; most practice only one or two of them.

1. Holding Tank-Separator - The oil-water mixture, containing anywhere from 200 to 50,000 ppm oil, is held in a tank where gross oil-water separation occurs. Wet oil is periodically pumped from the top of the tank to a reclaim oil tank. The remaining oil-water emulsion is transferred to a batch chemical treating vessel. This and similar physical separation steps are often classified as primary treatment.

2. Chemical Treater - The emulsion is heated in the chemical treater to 100-150°F and chemicals added to break the emulsion. The chemicals used depend upon the nature of the emulsion, but acids, such as sulfuric or hydrochloric, calcium chloride, alum (aluminum sulfate), or ferric chloride are used, sometimes in sequence. For example, in one case, 95% sulfuric acid is introduced to lower the pH to 2-3, followed by brief air mixing and a 6-12 hour digestion period. Emulsion breaking is completed by adding calcium chloride and caustic soda, bringing the pH to 7.5 to 9.5.[34] The oil-water separation is often completed by adding coagulating agents such as alum, ferric chloride, or polyelectrolytes, usually polymers. A typical coagulation process may be represented as follows:

$$Al_2(SO_4)_3 + 3CaCO_3 + 3H_2O \longrightarrow$$

$$\underset{\substack{\text{(Aluminum}\\ \text{hydroxide}\\ \text{floc)}}}{2Al(OH)_3} + 3CaSO_4 + 3CO_2$$

The polyelectrolytes may be used as a primary coagulant or as an aid. Other aids such as sodium silicate, clay, lime, caustic soda, and soda ash are used to raise the pH and to control the agglomeration and the density of the floc which adsorbs the oil. Chemical treatment followed by floc separation is often designated as secondary treatment. Air flotation is one method used for floc separation; settling is an alternative.

3. Air Flotation - In dissolved-air flotation, minute air bubbles are formed by saturating the water with air under pressure followed by a reduction in pressure. The air bubbles become attached to the oily floc, floating it to the surface. Alternatively, the air can be introduced by turbine aerators or spargers. The floc or scum, which may contain greater than 90% water, is skimmed from the surface and sent to oil recovery equipment, or disposed of into lagoons, drying beds, land

spreading (sometimes for dust control), by deep well injection, or incineration.

4. Oil Recovery - Where oil quantities are sufficiently large, recovery may be achieved in the plant or by a waste oil processor by either thermal or acid treatment of the floc, with or without prior dewatering, and water evaporation from the wet oil recovered. The recovered oil can normally be used as a fuel. It may also be possible to reclaim some coagulant in this step. The economics tend to be questionable because of energy requirements, and in the case of acid treatment, because of corrosion and odor problems which must be solved. Waste solids may also result from this step, requiring landfill.

5. Final Water Cleanup - The water from floc separation often contains unsatisfactory levels of solids, dissolved organics, or other impurities. Further treatments such as biological oxidation, heavy metal ion precipitation, neutralization, or carbon adsorption may be necessary before discharge to streams or municipal treatment plants, or reuse of the water. Skimming of small quantities of oil may occur during these treatment steps.

It may be concluded from this discussion that the recovery of oil from emulsions with simultaneous water purification requires sophisticated chemical and engineering technology. The design of such systems requires detailed knowledge of flow rates, water and emulsion characteristics, and sludge and floc characteristics. Adequate design requires experimental data and often pilot plant demonstration.

OTHER PETROLEUM BASED-INDUSTRIAL OILS

The sources of these oils may number in the hundreds of thousands, including refineries, most industrial plants, governmental facilities, institutions, etc. Some may be disposed of onsite, especially when the quantities are small. As with oils recovered from emulsions, the waste oils may be used as a fuel, incinerated, used for dust control, protection against water and freezing for coal, ores, etc., and other miscellaneous uses. They may also find their way into lagoons and landfill. As noted earlier, this one category of miscellaneous oils, which includes the entire spectrum of petroleum and coke oven oil losses, could amount to more than one billion gallons per year.

The greatest single source of other petroleum-based waste oils are the refineries, where water treatment systems have been developed which internally recycle most oils back to "slop" tanks, thence to distillation for recovery. Little oil leaves the refinery complex except as dredgings, sludges, sediments, tank cleanings, spent catalyst and the like. These generally are landfilled or picked up by collectors, though lagoons are still used to some extent for waste liquid materials. Numerous descriptions of waste oil recovery and disposal facilities are available in the literature.[10, 33, 36, 40]

Oil recovery and disposal facilities available in conjunction with petroleum transportation, marketing, and use are not nearly so extensive, except within large industrial plants where extensive water treating is practiced. In small installations it is uncommon to find more than a oil/water separator to treat oily waters. Recovered waste oil is most often landfilled, used as fuel, or collected for road oiling or processing to fuels.

Oil-water separation at production facilities has become more sophisticated, often using heater-treaters (chemical emulsion breakers), air flotation, or sand filters. Recovered oils are fed to pipelines where possible, turned over to collectors, or disposed of, for example to help stabilize sandy soils.

WASTE VEGETABLE, ANIMAL AND FISH FATS AND OILS

Fats and oils are recovered from wastewater and purified for use in soapmaking. Recovery requires process steps similar to some of thos discussed in the Section on emulsified oils, though as complete a treatment as indicated by all those steps would be unusual at the present time. A 1965 survey of types of treatment in meat packing and processing plants is shown in Table 12. A more recent survey, if available, would show increased use of more effective techniques for oil recovery and disposal, including chemical

Table 12. TYPES OF WASTE TREATMENT EMPLOYED BY 108 MEAT PACKING AND PROCESSING PLANTS*[35]

Method	No. of Plants
Screening	59
Sedimentation	71
Filtration	2
Flotation (air)	11
Flotation (gravity)	87
Flocculation	2
Evaporation	2
Chemical coagulation	1
Trickling filter	1
Activated sludge	12
Anaerobic digestion	5
Septic tank	13
Irrigation	2
Stabilization pond	7

* From "Water in Industry," National Association of Manufacturers, January, 1965.

coagulation, air flotation, and biological treatment.

A recent EPA project describes a system for recovery of fatty materials from edible oil refinery effluents, including the upgrading of fatty materials by caustic and sulfuric acid treatment followed by a centrifuge to separate oil, water, and waste sludge phases.[41]

OIL/WATER MIXTURES FROM MARINE SOURCES

Ballast, bilge, and tanker washing wastewaters contaminated with oil are disposed of at sea, to refinery terminal facilities, to independent facilities, and, in the case of U. S. Naval vessels, to Naval stations. The recovery of oil in onshore facilities ranges from those integrated with refineries, already discussed, to simple settlers from which oil is recovered as a fuel. Most such facilities recover the bulk of the oil but many may still be discharging oil contaminated water.

Other sources of similarly contaminated oils may arise from offshore drilling, production, transportation, and mooring facilities.[42]

SECTION VII

FOREIGN WASTE OIL DISPOSAL AND RECYCLE TECHNIQUES

Waste oil recycle appears to be practiced much more intensively in Europe than in the U. S. Tax incentives and subsidies by European governments are a major reason. On the other hand, plants producing lubes operating in Japan during the 1950's and early 1960's, based on imported dehydrated drain oils, are believed to have been shut down in favor of virgin lube production. Little is known about waste oil practices elsewhere in the world.

The basic processing steps being used in Europe for rerefining are essentially the same as those available in the U. S. These are distillation, solvent extraction, and acid, clay, and hydrogen treating. Each of these will be discussed in turn.

Most of the information here is based on recent discussions in Europe between Dr. Peter B. Lederman, Director of the Industrial Waste Treatment Research Laboratory, and various people knowledgeable about European practice.[20]

DISTILLATION

At least one plant in France uses distillation followed by acid and clay treatment. Furnace coking is a problem in this plant. Operation and maintenance were found to be problems in earlier German trials with distillation.

SOLVENT EXTRACTION

The propane extraction process was described in detail in an earlier section. It consists of flash dehydration, propane extraction, and mild acid/clay treatment.[19] IFP's propane extraction process is operated by Viscolube in Milan, Italy. Plant operation is satisfactory except for combustion of the extraction bottoms product which, blended with fuel oil, contains about 25% solids. Furnace tubes are fouled,[20] and presumably particulates are emitted to the atmosphere.

ACID/CLAY TREATMENT

Bernd Meinken, a small German engineering consulting firm, appears to be the most significant factor in European acid/clay treatment technology. They have been responsible for about 30 plants in Germany, Sweden, and elsewhere.

The basic Meinken technology is similar to U. S. practice, but plant descriptions indicate semi-continuous operation with instrument sophistication unknown in the U. S. re-refining industry. Special dehydration tower and acid treater designs are claimed to be superior to competing practices. The use of circulating hot oil heaters to replace fired heaters reduces skin temperatures and minimizes heater fouling by waste oils. This approach is used in only one U. S. plant as far as is known.

Acid sludge is neutralized with clay and/or caustic and disposed of or burned in an incinerator at 1000°C (1832°F). The incinerator flue gas is diluted with cold air so that SO_2 emissions, stemming from the waste acid, do not exceed 0.2-0.3% volume percent (2000-3000 ppm). Particulates from the acid sludge and clay are presumably also emitted.

In another scheme, for fuel oil production, phenol containing wastewater is vaporized in a direct fuel fired heater and purified by incineration. Heat generated in the incinerator can be used for process purposes.

In a more recent version of the Meinken process, a development of Shamtom Lubricants and Chemicals, Ltd. (an Israeli firm), whereby the waste oil is pretreated with silicate, reportedly reduces acid requirement from about 5 to 2 volume percent.

HYDROGEN TREATMENT

No hydrogen treating plants for waste oils are now being operated. However, two new plants reportedly will replace acid/clay with hydrogen treatment because of regulations against acid discharge. These are a 36,000 gallon per stream day plant due to start up in Syracuse, Sicily during 1974, and a 20,000 gallon per stream day plant due to start up in Belgrade, Yugoslavia during 1976. It is believed that propane extraction will be used in these plants to prepare the lube fraction for hydrogen treating.

INDUSTRIAL WASTE OILS

A Meinken plant in Sweden makes heating oil from industrial waste oils. This is basically a dehydration/filtration operation. Fatty oils can be handled by increasing dehydration temperature from about 150°C (302°F) to 200°C (392°F) to decompose the fatty oils and drive them overhead.

SECTION VIII

ENVIRONMENTAL ASSESSMENT OF WASTE DISCHARGES FROM PROCESSING OF WASTE OILS

The adverse effects of oil released to the environment disposal have been widely discussed in the literature, and reviewed in an EPA report to Congress.[43] A qualitative summary of the various aspects of waste oil disposal can be found in Table 13. This discussion deals primarily with the description and effects of solid, liquid, and gaseous emissions from waste oil processing. A discussion of health and safety aspects is provided in Appendix G.

WASTE PRODUCTS GENERATED

Acid/clay waste oil re-refining plants produce two waste products: acid sludge and spent clay. At least two re-refiners, who pretreat with caustic or a caustic-silicate mixture, also product a waste caustic sludge.

The distillation/clay process produces a high ash bottoms product and spent clay. At least one processor uses a pretreatment step which results in a high solids content sludge recovered by centrifugation. The sludge may be acidic or basic depending on whether caustic is used. Other processors are known to filter raw drain oil, producing a high solids content sludge.

The following discussion will serve to characterize the major waste products encountered in re-refining, including air emissions and wastewater. Environmental regulations and disposal practices are discussed later in this Section.

Acid Sludge

Sulfuric acid treating results in reactions with and dissolving of metal salts, aromatic and asphaltic compounds, organic acids, water, and other polar compounds. A phase separation occurs whereby acid sludge settles and is removed from the treating vessel leaving relatively pure oil behind. For a five volume percent acid treatment (about 10 weight percent), sludge production is about 0.15 gallons per gallon of lube product, or about 0.1 gallons per gallon of drain oil.

TABLE 13. THE TREATMENT AND DISPOSAL OF WASTE OILS AND WASTE OIL RESIDUES

WASTE OILS	SOURCE	COMMON CONTAMINANTS (also see Tables for Additives)	PRIME CONTAMINANTS LIMITING REUSE OR SIMPLE DISPOSAL	PRINCIPAL TREATMENT AND DISPOSAL METHODS NOW USED (Disadvantages)
Automotive Lubricants (primarily crankcase oil, but contains transmission fluid, gear lubricants, hydraulic oil, solvents, brake fluid, possibly antifreeze)	Automotive Service Facilities (incl. discarded filters, and discarded vehicles)	Compounds of N,O, and Cl, water, gasoline, metal and carbon particles, Pb and other metal compounds (See Tables 1 and 2 for further detail)	Color and odor bodies (N and O compounds), suspended inorganics	1. Re-refining (residue disposal) 2. Fuel (tube deposits and particle emission) 3. Road oil and dust control (runoff)
Railroad Diesel Lubricants (primarily diesel lube, but may contain journal oil, gear lubricants)	Railroad Service Facilities	Similar to automotive lubricants, but no Pb	Color and odor bodies (N and O compounds), suspended inorganics	1. Re-refining (residue disposal) 2. Fuel (tube deposits and particle emission) 3. Road oil and dust control (runoff)
Truck Diesel Lubricants (primarily diesel lube but may contain transmission fluid, gear lubricants, hydraulic oil, etc.)	Truck Service Facilities	Similar to automotive lubricants but no Pb	Color and odor bodies (N and O compounds), suspended inorganics	1. Re-refining (residue disposal) 2. Fuel (tube deposits and particle emission) 3. Road oil and dust control (runoff)
Metal Working Lubricants (often emulsified with water)	Metal Working Plants	May contain fatty oils, S,N,Cl,F from original fluid + metal particles, oxidation and degradation compounds, sediment	Metal particles, sediment	1. Chip extraction and settling at elevated temp. (oily solid wastes) 2. Settling & Skimming (oily water waste & oil flocs and sludges) 3. Incineration (particle and other emissions)

TABLE 13. THE TREATMENT AND DISPOSAL OF WASTE OILS AND WASTE OIL RESIDUES (Continued)

WASTE OIL RESIDUES	SOURCE	COMMON CONTAMINANTS	PRIME CONTAMINANTS LIMITING REUSE OR SIMPLE DISPOSAL	PRINCIPAL TREATMENT AND DISPOSAL METHODS NOW USED (Disadvantages)
Acid Sludge (93-98% Sulfuric acid/oil sludge, on the order of 30% water soluble)	Acid treating of waste oils to remove metals and other contaminants	H_2SO_4, Pb from crankcase oils, metals and metallic compounds, polymers, heavy oil residues - (see Tables 15-17)	H_2SO_4, Pb, and other metals, oil	1. Landfill with or without mixing refuse (water pollution) 2. Lagoons (temporary)
Caustic Sludge (caustic, sodium silicate, water, metals, oily sludge)	Caustic treating of waste oils to break emulsions	NaOH, Na silicates, Pb and other metallic compounds	Pb and other metals, oil	1. Landfill (water pollution, slow degradation) 2. Lagoons (temporary)
Spent Clay (oil and impurity contaminated clay cake)	Clay treating of waste oils to remove impurities, improve odor and color	Oil, organics containing N and O (see Table 18)	Oil and other organics	1. Landfill (water pollution, slow degradation)
Pretreat Residues (sludge of oil, water, and inorganic residues)	Residues from settling, filtration, centrifugation, and other pretreatments	Pb from crankcase oils, other metals and metallic compounds, heavy oil residues (also discarded filter papers, cloths, filter aids)	Pb and other metals, oil	1. Landfill (water pollution, slow degradation)
Distillation or Extraction Bottoms (heavy oil fraction high in inorganics)	Distillation or extraction to concentrate non-volatile contaminants	Pb from crankcase oils, other metals and metallic compounds, heavy oil residues, coke	Pb and other metals	1. Lagoons (temporary) 2. Asphalt 3. Fuel (air pollution)

TABLE 13. THE TREATMENT AND DISPOSAL OF WASTE OILS AND WASTE OIL RESIDUES (Continued)

WASTE OIL RESIDUES	SOURCE	COMMON CONTAMINANTS	PRIME CONTAMINANTS LIMITING REUSE OR SIMPLE DISPOSAL	PRINCIPAL TREATMENT AND DISPOSAL METHODS NOW USED (Disadvantages)
Odors	Acid and other processing steps, Water Treatment, Vents, Open Tanks, Leaks	May be trace hydrocarbons, solvents, organic acids, esters, O, N, S containing compounds, SO_2, SO_3, NH_3, etc.	Odors	1. Scrubbers (water pollution) 2. Vent to furnaces
Condenser Liquids (water from oil and stripping steam & light hydrocarbons; condensed steam and cooling water where steam jet vacuum with barometric condenser used)	Distillation Overheads	Phenols, other dissolved organics, oil	Emulsions, dissolved organics	1. Separators (poor efficiency, wet oil residue) 2. Separators/Cooling Towers/Recycle (water pollution from blowdown)
Scrubber Waters (usually aqueous NH_3 or caustic with impurities)	Gas Scrubbing to eliminate SO_2, SO_3, and other volatile acids	NaOH or NH_4OH, SO_2, SO_3, water soluble organics	Water soluble organics	1. Recycle (water pollution from blowdown) 2. Acid treatment of blowdown (dissolved solids residue)
Runoff and Other Oily Waters	Oily Waters from spilled oils, Leaks, Cooling Tower Blowdown, Other Sources	Oil, dirt	Oil	1. Separators (poor efficiency, dirt/wet oil residues) 2. Impoundment for reuse (possible water pollution)
Ash and Coke	Furnace Tubes and Other Piping	Metallic compounds, polymer, coke	--	1. Landfill (water pollution from ash solubles)

TABLE 13. THE TREATMENT AND DISPOSAL OF WASTE OILS AND WASTE OIL RESIDUES (Continued)

WASTE OILS	SOURCE	COMMON CONTAMINANTS (also see Tables for Additives)	PRIME CONTAMINANTS LIMITING REUSE OR SIMPLE DISPOSAL	PRINCIPAL TREATMENT AND DISPOSAL METHODS NOW USED (Disadvantages)
Other Industrial Oils (turbine oils, transformer oils, lubricants, hydraulic oils, heat transfer fluids, synthetic oils, etc.)	Industrial Plants, Power Plants (incl. discarded transformers and machinery)	Turbine Oils: water, oxid-products Transformer Oils: water, oxid-products, polychlorinated oils, Gear oils: S, Pb, dirt, wear metal, water, oxid-products	Metal particles, water, degradation products	1. See methods for automotive lubricants 2. Clay treating (spent clay waste) 3. Filtration (filter aid and particle waste) 4. Centrifugation (particle waste) 5. Recovery to prepare soluble oils 6. Incineration (air pollution)
Animal & Vegetable Fats & Oils (Solids or Liquids)	Food & Textile Plants	Coagulants from oil recovery, trace contaminants including metals	Color, odor	1. Recovery and reprocessing for soap manufacture
Oily Water	Industrial Plants, Refineries, Marine Service Facilities, Fuel terminals, Oil Spill Cleanup	Sand, dirt, salts, virgin oil metals such as V, Ni, Fe, foreign matter such as sorbents	Emulsions, soluble organics, foreign matter	1. Separators (poor efficiency, wet oil waste) 2. Biochemical treatment (expensive, sludge waste) 3. Combined Municipal/Industrial wastewater plants (pretreatment necessary, possible toxic materials, sludge waste) 4. Physical/chemical treatment (expensive, water contamination with chemicals)

TABLE 13. THE TREATMENT AND DISPOSAL OF WASTE OILS AND WASTE OIL RESIDUES (Continued)

WASTE OILS	SOURCE	COMMON CONTAMINANTS (Also see Tables for Additives)	PRIME CONTAMINANTS LIMITING REUSE OR SIMPLE DISPOSAL	PRINCIPAL TREATMENT AND DISPOSAL METHODS NOW USED (Disadvantages)
Oily Sludges, Tars, Scums, Flocs	Tank Cleaning, Refineries, Coke and Petrochemical Plants, Oil Spills, Wastewater Treatment	Coke particles, S, N, O, halides, coagulants, water	Solids, S, N, O, halides	1. Incineration (possible air pollution) 2. Landfill (water and air pollution) 3. Ocean disposal (water pollution) 4. Lagoons (temporary)
Offspec and Contaminated Fuels	Refineries, Tank Cleaning, Airports, Pipelines, Fuel Terminals, Marine Service Facilities	Light hydrocarbons, sludges, solvents, water, salts, trace contaminants	Emulsions, sediments, color, odor	1. Distillation (possible water and residue problems) 2. Fuels (possible air pollution) 3. Incineration (possible air pollution)

Some of the characteristics of the sludge are presented in Tables 14-16. Since little data is available, it is not known whether these analyses are typical. The high acid content requires that sludge be handled as carefully as the original acid. As much as 30-50% of the acid sludge is water soluble, complicating land disposal. Lead content, believed to be in the 2 to 10% range, primarily as sulfate, is another important factor to be considered.

The acid sludge is similar to some sludges produced in petroleum refineries. The volume of these refinery sludges has been decreasing as hydrogen treating has replaced acid treating. Petroleum refineries have disposed of acid sludges by incineration, acid recovery, landfill, and neutralization with disposal to wastewater.

All acid sludge disposal by U. S. re-refiners is to landfills or lagoons, usually without neutralization. Neutralization and incineration, practiced in Europe, leads to high SO_2 emissions. Acid recovery is too expensive on a small scale and transportation costs are too high to justify centralized recovery plants. Disposal to wastewater can only be practiced where high volume wastewater treatment facilities are available for dilution.

Caustic Sludge

Caustic sludge is generated from emulsion breaking of waste oils. Only two re-refiners in the U. S. are known to be definitely using this approach, though other waste oil processors may be doing so. The sludge contains caustic, sodium silicate, lead and other metals, and oily sludge. No analyses of caustic sludge have been found.

Spent Clay

Although little data is available, the clay recovered from re-refining filter presses is believed to contain about 10-40% oil. At 0.4 pounds of clay per gallon of oil treatment rate,this results in a 0.5 to 2% oil loss. An analysis for spent clay from petroleum refining is provided in Table 17. Minor components in the spent clay may include oxygen and nitrogen containing polar organic compounds, carbonaceous residues, acid residues, and other polar compounds.

Spent clay is ordinarily disposed of to a landfill, though some uses have been found. For example, clay containing oil has been used as a surfacing material for stables

Table 14. ACID SLUDGE ANALYSIS

Derived from 1971 Re-Refiner Data for sulfuric acid treated sludge.

	WT. %	
	Diesel	Stock*
% Acid	47.5	40.8
Ash Sulfate	4.45	11.26
Sulfur	14.9	14.1
Sulfur calculated from % acid assuming H_2SO_4	15.5	13.3
Combustibles	----30-42-----	

ELEMENTAL ANALYSIS, ppm

	Diesel	Stock*
Cu	40	40
Al	40	140
Fe	500	1,100
Si	800	1,400
Pb	1,000	20,000
Aq	14	0
Zn	200	2,100
Ba	400	1,300
Cr	190	50
Ca	12,600	6,400
Na	200	4,000
P	1,000	4,300
B	40	50
Ni	10	30
Sn	35	30
Mg	70	1,000
	17,139	41,940
	1.71%	4.19%
Sulfated ash by calculation from elemental analysis	5.35%	9.39%

* From independent collectors. All or primarily crankcase oil.

Table 15. ACID SLUDGE ANALYSIS*

	WT. %
SOLUBLE IN WATER	
Ash	4.2
Acid (H_2SO_4)	27.0
INSOLUBLE IN WATER	
Ash	8.4
Acids	1.6
Volatiles (150°C. @ 1 mm Hg)	0.8
Lube Oil (naphthenes, paraffins, aromatics)	15.5
Polymers	15.6
Other Polar Compounds	1.8
Ashphaltenes and Other Residues	24.4
	99.3

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* Derived from Putscher[24]

Table 16 PHYSICAL CHARACTERISTICS OF ACID SLUDGE

From 1971 Re-Refiner Data for sulfuric acid sludge

Density, lbs/gal.	10.0
Viscosity, SSU	
75° F.	4,000,000
105° F.	457,000
125° F.	150,600
pH	0.1

Table 17 ANALYSIS OF PETROLEUM REFINING SPENT CONTACT CLAYS[44]

	AVERAGE	RANGE
BTU/lb.	6000	1000 - 9250
Particle Size, sieve no.	170	30 - 300
Volatile Solids, wt. %	14	0 - 55
Ash, wt. %	53	0 - 99.8
Water, wt. %	8	0 - 36
Oil, wt. %	19	1 - 45
pH	5.6	3.5 - 7.5

and unpaved road stabilization. Petroleum refineries have regenerated clays by incineration for re-use and disposal, but this approach is expensive on a small scale.

Other Residues

A variety of other solid, semi-solid, or liquid residues may result from waste oil processing, including tank cleaning sludges, furnace coke, combustion ash, wastewater flocs and scums, etc. All of these are normally disposed of with refuse or separately landfilled, though oil recovery by dewatering and blending may be practiced on some tank sludges.

Distillation Bottoms

When drain oil is purified by vaporizing the desired product, leaving behind high boiling and non-volatile materials, the residue becomes a waste disposal problem. The residue, or distillation bottoms, is considerably higher in ash, sulfur, nitrogen, oxygen, and acidity content than the lube product. Total ash may reach 10-25%, with lead contents ranging from 5-15% depending on the fraction not vaporized, on the ash and lead contents of the drain oil, and on the extent of pretreatment.

Distillation bottoms have been used as an asphalt blending stock, or they have been stored in lagoons. An EPA grant program is underway to demonstrate the utility of this material as a fuel in secondary lead smelting.

Air Emissions

A properly controlled processing plant will emit few contaminants to the atmosphere. Early plants contained many open vessels, but few of these are now left. Vents from process and wastewater treatment units and storage tanks in many re-refining plants are discharged to a furnace where vented combustible materials are burned. In other plants caustic or ammonia scrubbers are used.

Little is known about the actual composition of the gases, but some odors are apparent around most re-refining facilities. The odors are no worse and probably somewhat less intense than those encountered around petroleum refineries. Most likely these odors are caused by esters and other organic compounds containing oxygen and nitrogen. Very low concentrations of organic sulfur compounds may also be present, as well as some SO_2 and SO_3 from acid sludge handling where acid treating is practiced.

Wastewater

The wastewater from a re-refining plant comes from several sources: water separated from the raw drain oil; cooling water used in indirect heat exchange; cooling water contaminated by direct contact with oil, e.g. in the barometric condenser of a vacuum system; water from condensed steam which contacts oil, e.g. in steam jet vacuum systems, or stripping steam; vent gas scrubbers; and plant runoff water. Both acid/clay and distillation/clay plants are equipped with oil/water separators and neutralization facilities to handle the process water separated from the oil. Vacuum distillations are usually performed with steam jets and barometric condensers, requiring oil/water separation for these effluents as well. Cooling water used indirectly is sometimes provided on a once-through basis with no treating, sometimes recycled with the aid of a cooling tower, and occasionally joined to other water streams entering an oil/water separator. Some re-refiners also provide for oil/water separators on runoff water.

In the best operations, all direct contact condensers are replaced by indirect air or water cooling; and steam use is minimized by providing efficient mechanical vacuum pumps. Maximum water recycle is practiced with efficient oil separation from the process and runoff waters. Purge water is sent to a municipal sewer plant or trucked to a landfill site. Advanced wastewater treatment systems for "zero" emissions are not now in use.

The characteristics of wastewaters obviously depend upon the type of oil processed, the nature of the process and of wastewater treatment facilities, housekeeping, the degree of recycle, and other factors. However, one expects to find traces of metals which appear in the raw oils, dissolved and suspended solids, dissolved phenols and other organics, and suspended or emulsified oil. These expectations are borne out by samples obtained by the contractor and analyzed. These are discussed in the following section.

CHARACTERIZATION OF WASTEWATERS FROM OIL RECYCLING FACILITIES

Wastewaters from a marine waste oil processing plant and from a re-refining facility were sampled and analyzed as part of the program to understand potential pollution problems associated with waste oil recycling. Re-refining crankcase waste oils to lubes is of interest because it is one major type of recycling. Other waste oil processing plants are much more variable in type. The marine waste oil processing plant was chosen mainly because it discharged a relatively large quantity of water from an oil/water separator.

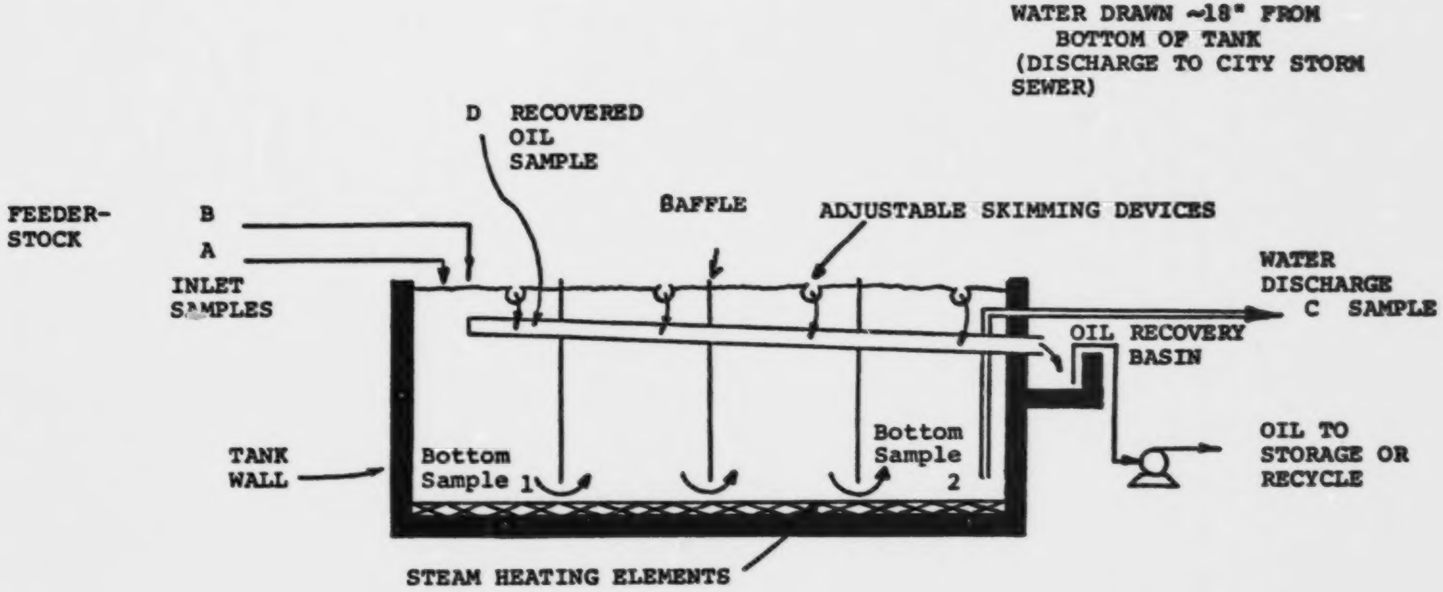
The Marine Waste Oil Processing Facility

This facility consisted of an oil/water separator with two inlets, one water discharge, and an oil recovery system (Figure 5). The recovered oil is pumped to storage. Samples were obtained from the inlet and discharge streams, the bottom of the separator unit itself, and from the recovered oil.

The separator receives feed from tanks used to store oil/water mixtures from a tanker Butterworth steam cleaning system. The feed varies continuously in percentage of oil and water, salinity, and type of oil. The recovered oil from the separator is sometimes recycled to the separator to further reduce the water content. The finished oil is stored, blended, and burned in the plant boilers which produce steam for Butterworth and other operations. The amount of oil recovered from the operation is estimated to be one million gallons per year.

The oil/water separator has an approximate holding capacity of 14,000 gallons and is operated at a temperature of 120°F. The unit is divided into a series of compartments by steel plates which separate the oil at the surface and allow water to pass underneath toward the discharge pipe. At the surface, pipes cut in half are used as troughs to draw off the top layer of oil, emptying it into a basin. From there the recovered oil is pumped to storage or recycled thru the unit.

The wastewater is discharged from the unit by gravity flow via a 4 inch pipe which draws from the bottom of the separator. The wastewater is then piped into a city storm sewer which empties directly into the saline harbor. The residence time in the tank was calculated to be 3.6 hours with a discharge rate of 3,900 gallons per hour, operating


WATER DRAWN ~18" FROM BOTTOM OF TANK (DISCHARGE TO CITY STORM SEWER)
D RECOVERED OIL SAMPLE
FEEDER-STOCK
B
A
INLET SAMPLES
BAFFLE
ADJUSTABLE SKIMMING DEVICES
WATER DISCHARGE
C SAMPLE
OIL RECOVERY BASIN
TANK WALL
Bottom Sample 1
Bottom Sample 2
OIL TO STORAGE OR RECYCLE
STEAM HEATING ELEMENTS

WASTE OIL PROCESSOR

OIL-WATER SEPARATOR UNIT

Figure 5

over an 8 hour day. The discharge rate was measured by timing the accumulation of five gallon quantities.

The Lube Oil Re-Refining Facility

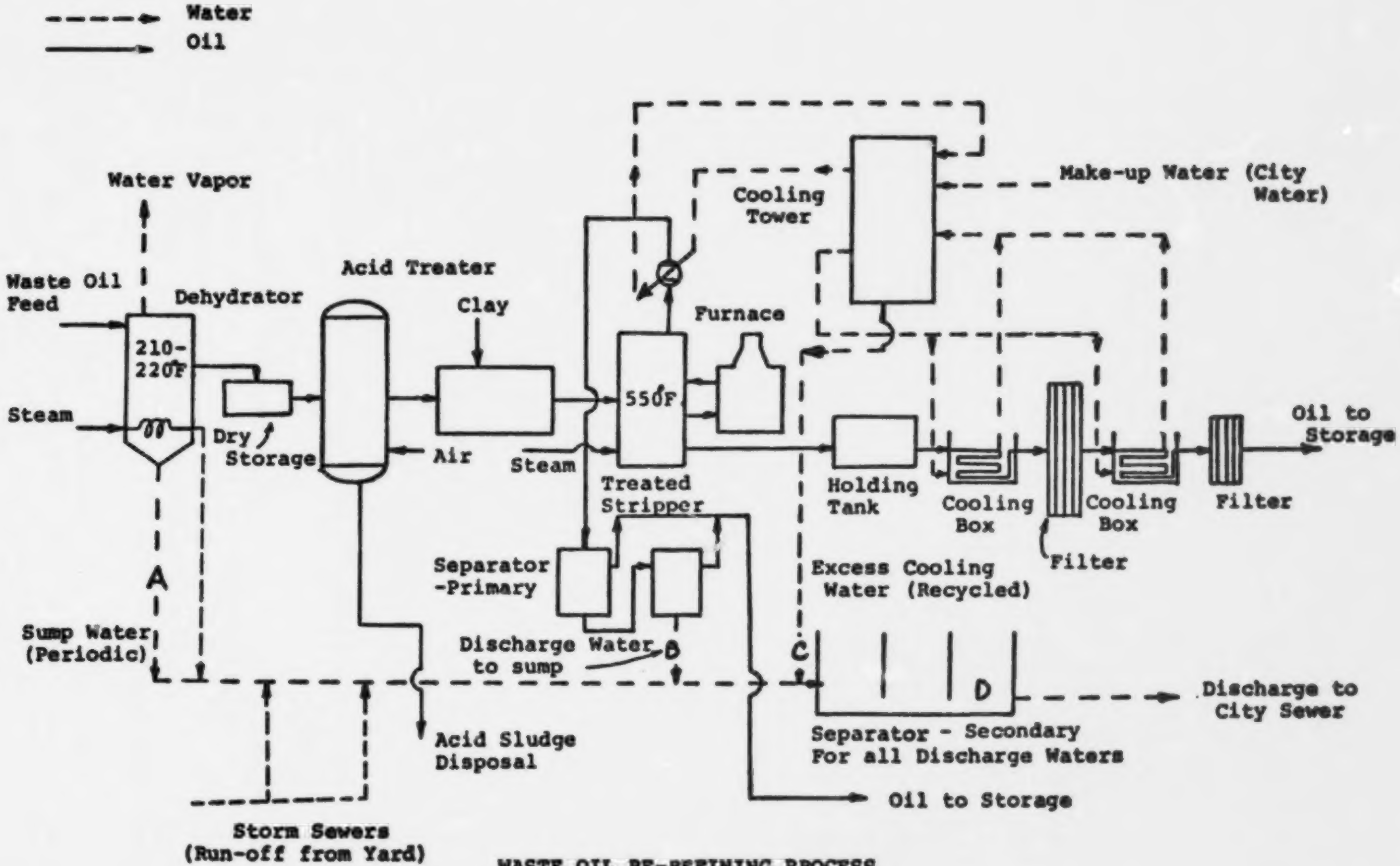
The re-refining facility uses acid and/or clay to process both automotive crankcase drain oils and industrial waste oils. The oil is processed in approximately 7,000 gallon batches with an estimated daily production of about 20,000 gallons. The oil/water separator handles both process wastewaters and storm water runoff.

Unfortunately, many of the wastewater streams at the refinery were underground, making them inaccessible for sampling. Water samples were collected from the primary separator, which handles the clay treater/stripper overhead; sump water accumulated in the dehydrator; purge water from the cooling circuit; and the bottom of the separator near the discharge pipe. The actual discharge line was inaccessible.

The acid-clay refining operation is illustrated in Figure 6. The feedstock is pumped from storage to the dehydrator which operates between 210 and 220°F., using an air-sparger to mix the oil. The water vapor overhead is released directly to the atmosphere. A small quantity of water is periodically discharged from the bottom of the dehydrator (sampling point A). The dehydrated oil is sent to dry storage.

Dry oil is later pumped to the acid treating units. Acid sludge from the units are hauled to another site, neutralized and discarded in a landfill. The acid-treated dehydrated oil is transferred to the clay treating operation where clay is added, forming a slurry which is pumped to the clay contact/stripping column. The temperature of the batch is brought up to 550°F. by circulating through the column and the furnace, with the light fuel fractions going off overhead. Steam is added to the bottom of the column for agitation and to aid stripping. The overhead vapor, consisting of light oils and water, is condensed and separated. The light oils are sent to storage, and the wastewaters to a sump (sampling point B).

The hot oil containing the clay is passed through a cooling box to reduce the temperature to approximately 230°F. before being filtered in the first press. A second cooling box further reduces the temperature to 150°F. prior to the


Water
Oil
Water Vapor
Waste Oil Feed
Dehydrator
210-220F
Steam
Dry Storage
Acid Treater
Clay
Air
Steam
550F
Furnace
Treated Stripper
Cooling Tower
Make-up Water (City Water)
Separator -Primary
Discharge Water to sump
A
B
C
D
Sump Water (Periodic)
Acid Sludge Disposal
Storm Sewers (Run-off from Yard)
Holding Tank
Cooling Box
Filter
Cooling Box
Filter
Oil to Storage
Excess Cooling Water (Recycled)
Separator - Secondary For all Discharge Waters
Discharge to City Sewer
Oil to Storage

WASTE OIL RE-REFINING PROCESS

Figure 6

final or backup filter. The re-refined oil is then pumped to storage.

Condensed steam, run-off water from the refinery yard, and all wastewater streams from the operation run directly through a sump to the main oil-water separator before being discharged to a city sewer. The estimated discharge rate from the re-refining process is 10,320 gallons per day, excluding runoff water from the yard. At this rate a calculated residence time for the main oil-water separator unit is 28 hours. Including runoff waters from the yard, the rate of discharge is greatly increased and the residence time is significantly decreased. For example, with a three inch rainfall within a 24 hour period and all runoff waters going through the separator unit, the total discharge volume was calculated to be about 700,000 gallons per day, reducing the average residence time to only 30-35 minutes.

Sampling Procedures

Due to differences in the two waste oil processes, the sampling procedure varied. Duplicate samples at the final discharge point were taken in both cases.

Marine Waste Oil Processing - For the marine waste oil processing operation, inlet and discharge samples (see Figure 5) were taken directly from the process stream in a plastic bucket and then transferred to prepared sample bottles. Bottom samples from the separator unit were drawn using a ten foot by 1/2 inch aluminum pipe. The pipe was plugged at one end, and the other end submerged to the bottom of the tank. The plug was then removed allowing water to enter the pipe. Replugging the pipe, it was withdrawn and emptied into appropriate sample bottles.

Re-Refining - For the waste oil re-refining operation the wastewater streams were sampled as follows (see Figure 6);

> At sample point A, wastewater discharge from the bottom of the dehydrator was obtained by opening a valve and filling the sample bottle. Only a small quantity of water could be collected at this point.
>
> At sample point B, wastewater condensed with the clay contact/stripper overhead and passed through a separator empties directly into the sump. Sample bottles were placed directly under the discharge pipe, rinsed several times, and filled.

At sample point 6, purge water from the cooling tower was dumped into the same sump. Samples of the purge water were also obtained by rinsing and filling bottles directly under the outlet pipe.

At sample point D, the combined or total discharge (released to the city sewer) for the entire re-refining process passes through the bottom of the last compartment of the secondary oil-water separator. A weighted one liter glass stoppered sampling bottle was lowered to the bottom of the separator unit near the discharge pipe and opened at that point by the use of a second cord. The bottle was pulled to the surface*, emptied, and the process repeated to obtain enough sample for all analyses in duplicate. This unorthodox method of sampling was necessary because discharge pipes leading to the city sewer system were underground and inaccessible.

In all sampling operations the appropriate preservatives were added to samples where required and all samples were transported in ice chests. The pH and temperatures were measured and recorded onsite and unless otherwise noted, all samples were collected, labled, preserved, and stored in compliance with EPA recommendations.[45]

Analyses

All analyses were conducted in accordance with EPA's "Methods for Chemical Analysis of Water and Wastes,"[45] or "Standard methods for the Examination of Water and Wastewater,"[46] when referenced by the EPA methods (phenol compounds, pH, BOD_5, elemental spectrographic analysis). The analyses performed on the samples collected were:

Oil and Grease
BOD_5
COD
TOC
Total Solids
Suspended Solids
Dissolved Solids
Nitrates
Phenols
pH
Elemental Spectrographic Analysis

---

* Due to the sampling bottle being open as it was pulled up thru the oil layer contamination of the water sample with oil is possible and thus reflected in the data (see Table 19, Discharge Samples).

Results of analyses and explanatory footnotes pertinent to the sampling method or sample handling are found in Tables 19 and 20.

Discussion of Results

Waste oil re-refining and processing operations appear to discharge a relatively small quantity of wastewaters per unit volume of product when storm runoff waters are not considered.

The operations sampled did not have direct means of measuring wastewater flow rates. Therefore, for both operations the discharge rates were calculated from measurements taken in the field or extrapolated from records of purchased city water.

Sampling point accessibility created no problem except in the case of the discharge stream to the city sewer of the re-refining operation, as previously explained. This problem illustrates the necessity for provision of adequate sampling facilities for wastewater discharge.

Analytical methods for analysis of oily wastewaters require further investigation and standardization to overcome the influence of non-homogeneity due to oil globules in the water sample. An example is the total organic carbon (TOC) analysis. It seems likely that oil globules can greatly alter the TOC values, depending upon the manner in which the sample is handled prior to injection into the analyzer. The COD and BOD values can also be influenced by oil globules.

Specific Federal effluent guidelines have not been established for waste oil recycling facilities. However, it is interesting to compare the results obtained in this study for the marine oil processor with maximum Federal guidelines proposed for discharge into surface waters by petroleum refiners, and for some typical restrictions for discharge to municipal treatment plants:

	Effluent Discharge Measurement for Marine Oil Processor	Federal Guidelines	Typical Municipal Restrictions
Oil & Grease, ppm (avg.)	95	10	100
BOD_5, ppm (avg.)	19	9	300
COD, ppm (avg.)	192	31.7	700
TOC, ppm	60	7.7	---
Phenol, ppm	15.5	0.07	---
Suspended Solids, ppm	304	5.8	350

The processor effluent would appear to be suitable for discharge to municipal treatment, but not to surface waters. The re-refiner effluent has not been compared because the high contaminant levels measured may be due to the sampling procedure, as previously explained.

TABLE 18. WASTE OIL PROCESSOR (MARINE WASTE OILS)
OIL/WATER SEPARATOR

SAMPLE	BOD_5	COD	TOC	OIL	PHENOL COMPOUNDS	pH	NITRATES	TOTAL SOLIDS	DISSOLVED SOLIDS	SUSPENDED SOLIDS	EMISSION SPECTRAL SURVEY g/l
Discharge C 12:00 Noon	mg/l 16.5	mg/l 90	mg/l 56	mg/l 103	mg/l 14	@ 45° C. 6.7	mg/l 0.05	mg/l 23,000	mg/l 23,000	mg/l 305	Na(2.1-21.); Mg, Ca(.2-2.1); Fe,Si (.002-.021); Al, Mn,B(.0002-.002)
C 2:15 PM	22.7	295	64	87	17	6.7	0.70	22,000	22,000	304	Na(2.1-21.);Mg,Ca (.21-2.1); Fe,Si (.002-.021); Mo, Cu(.0002-.002)
Inlet A 12:00 Noon	23.8	290	64	317	14	7.4	0.25	22,000	23,000	291	Na(1.0-10.); Mg, Ca(.10-1.0); Fe, Si(.001-.01);Mn, B(.0001-.001)
B 2:00 PM	---[2]	1,210	8,500	9,544	---[2]	6.3	0.60	15,000	14,000	969	None (1.7-17.0); Fe,Mg,Na(.17-1.7); Al,Si,Pb,Ba-Cr, Mn,Ni,Mo,V,Cu,Zn, (.017-.17); Zr, Ca,Ti(.0017-.017)
Recovered Oil D	---	---	---	---	---	---	---	---	---	---	Fe,Ma,Na,Ca(.19-1.9); Al,Si,V, (.019-.19); Cr,Sb, Pb,Mn,Ni,Cu,Zn,Ti, Ba(.0019-.019)
Bottom Samples											
#1	---	---	---	178,000	---	---	---	---	---	---	------------------
#2	---	---	---	159,000	---	---	---	---	---	---	------------------

[1] Waste waters were contaminated with sea water since they resulted from tank cleanings from marine tankers.

[2] Due to a large amount of oil present in sample, no color developed when titrated for BOD analysis. The large amount of oil also interfered with the phenol determination.

TABLE 19. WASTE OIL RE-REFINER

SAMPLE	BOD_5	COD	TOC[5]	OIL	PHENOL COMPOUNDS	pH	NITRATES	TOTAL SOLIDS	DISSOLVED SOLIDS	SUSPENDED SOLIDS	EMISSION SPECTRAL SURVEY[3]	
Discharge (D)[1]	mg/l	mg/l	mg/l	mg/l	mg/l	@ 15° C.	mg/l	mg/l	mg/l	mg/l	Strong	Medium
11:30 AM	2.7	(31,808[1])	163	(3,023[1])	92 (150)[2]	6.0	0.81[1]	959	511	394	Fe,Mg,Ca, Na	Si
Discharge (D)[1] 12:30 PM	4.0	(16,943[1])	182	(3,629[1])	84	6.1	0.64[1]	2256	931	401	Fe,Mg,Ca, Na	Si
Primary Separator Discharge (B)	6.0	792	127	168	89	4.1	0.25	493	483	4	Fe,Mg,Ca	Na
Cooling Tower Blow Down (C)	4.0	43	43	9	4	6.5	None detectable	180	172	7	Mg,Ca,Na	
Water From Bottom of Dehydration Unit (A)[4]	---	---	---	---	16	5.8	---	---	---	---	g/l Ca (.39-3.9); Fe, Si,Mg,Na(.039-.39); Al,Pb,Mn,Ni,B,Zn (.0039-.039);Mo, Cu,Co,Br (.00039-.0039)	

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[1] Discharge samples taken from bottom of secondary separator unit near discharge pipe by a special sample bottle to open underwater. However, samples may have been contaminated as sample bottle was pulled thru the surface layer of oil. This unorthodox method of sampling was necessary because all discharge pipes were underground and inaccessible.

[2] 150 mg phenolic compounds/l was reported by outside laboratory for sample D 11:30 AM.

[3] Concentrations reported as only "strong" or "medium" by outside lab.

[4] Only a small amount of water sample was obtainable from point A.

[5] TOC analyses were conducted excluding any large oil globules found in the samples.

EXISTING AND FUTURE REGULATIONS

While specific regulations covering the disposal of waste oils and emissions from the processing of waste oils do not exist at the Federal level, and are uncommon at state and local levels, existing regulations for solid waste disposal, water effluent limitation guidelines and new source standards, and air quality and emission standards do provide some protection against indiscriminate disposal. There is also a strong possibility that new laws and regulations in the areas of solid waste disposal, hazardous wastes, and air and water pollution control will provide further protection.

Solid Wastes and Land Disposal

On the Federal level, guidelines for disposal of solid wastes have been proposed[47] which, if promulgated, will establish EPA-recommended guidelines for adoption by state and local governments and for direct implementation by federal agencies.

These guidelines recommend against accepting wastes for incineration in municipal thermal processing installations if they are hazardous to human health or the environment, if the installation was not specifically designed for the waste, if the chemical and biological characteristics are detrimental to personnel or the facility, if legal requirements for air quality, water quality, health or safety will be violated.

For sanitary landfills, these guidelines generally are similar to the thermal processing guidelines, but recognize that it may be necessary to accept special wastes such as hazardous wastes, bulk liquids, semi-solids, wet sludges, flammable or volatile substances, and industrial process wastes, but special assessments are recommended such as site characteristics and nature and amounts of the wastes.

EPA has recommended to Congress that legislation be enacted to control hazardous waste disposal to the land.[48] It has compiled information on the types of materials in wastes which could be regarded as hazards to public health. A few types which may appear in some waste oils are compounds of heavy metals, including lead; organic halogen compounds, including polychlorinated biphenyls; miscellaneous organic compound, including carcinogens; and flammables. However, even when present in waste oils from automotive service and industry, these materials usually appear at low concentrations, with the possible exception of lead compounds, and flammables.

The proposed Hazardous Waste Management Act calls for authority to regulate the treatment and disposal of hazardous wastes.[48]

On the state and local level[49] few regulations deal with land disposal of waste oil residues. Some (e.g. Oklahoma City, Oklahoma) approve disposal procedures of liquids, hazardous materials and the like. Others (e.g. Chesterfield Township, Michigan) provide procedures which landfills must use if these types of wastes are received. California has set aside certain landfills suitable for chemical wastes to be used for that purpose. Still others (e.g. Westport, Connecticut) ban "dangerous explosive or inflammable materials." At least one state (New Jersey) requires that the waste producer provide sufficient information to the disposer to insure safe disposal of hazardous and/or chemical wastes; it also prohibits direct or indirect contact of chemical wastes (liquid or solid) with surface or ground waters.

Water

On the Federal level, the Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500 replaced all previous Federal water laws. The critical feature of this act requires effluent limitations consistent with "best practicable" control technology by July 1, 1977, and consistent with "best available" technology by July 1, 1983.

Pursuant to the 1972 law, EPA is issuing effluent limitations for twenty-nine industries, including petroleum refining and other industries where oil contaminated wastewater is likely to be encountered. In addition, this act gives EPA, the Coast Guard, and other agencies broad authority to clean up oil spills, make polluter pay costs of cleanup, and levy fines and penalties. Discharge of hazardous substances is also covered.

EPA has issued regulations to prevent oil spills into water, requiring potential "spillers" to prepare "Spill Prevention Control and Countermeasure Plans."[50] These regulations affect, for example, oil refineries, industrial users of oil, fuel oil dealers, drillers, bulk petroleum facility operators, and waste oil processors.

The Marine Protection, Research and Sanctuaries Act of 1972, effective on October 27, 1972, declared national policy "to regulate the dumping of all types of materials into ocean waters and to prevent or strictly limit the dumping into ocean waters of any material which would adversely affect human health, welfare or amenities, or the marine environment, ecological systems or economic potentialities."

On the state level, New Jersey, for example, has regulations specifically prohibiting discharge of oil refining "sludge acid," and deleterious, destructive or poisonous substances of any kind into any body of water.[51] In addition, New Jersey has prepared guidelines for "best practicable" technology for oil and petroleum based industries' emissions (guidelines are not standards and are subject to change)[52] which include, among other requirements, limits of 1.0 ppm for oil and grease, 0.05 mg/l for phenols, and 30 mg/l for TOC. The oil and grease guideline is considerably more stringent than the 10 ppm encountered in Federal effluent limitations, and very difficult to meet.

As another example, Illinois prohibits visible oil, unnatural sludge or bottom deposits, floating debris, odor, unnatural color or turbidity, and toxic or harmful concentrations of matter, and prescribes limits for many elements in the State's waters.[53]

In addition, Illinois prescribes maximum concentrations of contaminants which may be discharged:

Settleable solids, floating debris, visible oil, grease, scum, or sludge solids (referred to as offensive discharges)	None
Color, odor and turbidity	Below obvious levels

BOD and Suspended Solids(SS)	BOD_5 mg/l	SS mg/l
General	30	37
Sources with untreated waste load of 10,000 population	20	25
Specific situations	4-40	5-45
Effluent with dilution ratio of less than 5/1	10	12
Effluent with dilution ratio of less than 1/1	4	5
After 12/31/1977, sources with untreated waste load of 500,000 population	4	5

Bacteria, nitrogen, phosphorus, and the following are also regulated in effluents:

Constituent	Concentration mg/l
Arsenic (total)	0.25
Barium (total)	2.0
Cadmium (total)	0.15
Chromium (total hexavalent)	0.3
Chromium (total trivalent)	1.0
Copper (total	1.0
Cyanide	0.025
Fluoride (total)	2.5
Iron (total)	2.0
Iron (dissolved)	0.5
Lead (total)	0.1
Manganese (total)	1.0
Mercury (total)	0.0005
Nickel (total)	1.0
Oil (hexane solubles or equivalent)	15.0
pH	range 5-10*
Phenols	0.3
Selenium (total)	1.0
Silver	0.1
Zinc (total)	10.
Total suspended solids	15.0

*The pH limitation is not subject to averaging and must be met at all times.

Total Dissolved Solids shall not be increased more than 750 mg/l above background concentration levels unless caused by recycling or other pollution abatement practices, and in no event shall exceed 3,500 mg/l at any time.

Air

On the Federal level, the Air Quality Act of 1967 and the Clean Air Act of 1970 set primary and secondary standards of ambient air quality and directed the states to develop and implement plans to achieve the primary standards by 1975, with a possible two-year extension for technologically impossible situations.[54]

Standards have been set for sulfur oxide, particulate matter, carbon monoxide, hydrocarbons, photochemicals, and nitrogen oxide. In addition, special Federal authority exists to control new stationary sources, hazardous air pollutants, motor vehicle emissions, fuel and fuel additives, aircraft emissions, and low emission vehicle procurement.

Performance standards have been devised for five major stationary sources, and are proposed for seven others, including petroleum refineries and storage vessels.[55] For the petroleum refineries, particulates, carbon monoxide, and sulfur dioxide are regulated. For storage tanks, hydrocarbon emissions are regulated (indirectly, by specifying control measures).

National emission standards have been set by EPA for asbestos, beryllium, and mercury. Atmospheric lead is known to be a danger to human health, but national emissions standards have not yet been set, perhaps because in the EPA authority hazardous air pollutants were defined as "materials discharged into the atmosphere that have a proven relationship to increased human death rates."

On the state level, numerous approaches have been taken to achieve the air quality standards. Some of the relevant regulations include prevention of open burning, particulate, sulfur oxide, and hydrocarbon emission limitations, and nuisance rules covering odors.

DISPOSAL TECHNIQUES

The disposal of acid sludge from re-refining is the most serious of the various disposal problems faced by waste oil processors. Oily flocs and sludges from wastewater treating, residues from tank settling, and spent clay also present difficulties. Technology for wastewater treatment and the prevention of air emissions is available, but expensive.

Acid Sludge

Reconstitution of sulfuric acid from acid sludge has been done in connection with petroleum refining,[56] but this has not been and does not appear likely to be a significant method of disposal for re-refiners, primarily because the quantity is very small at each location.

Although even the total quantity of acid sludge from drain oil re-refining in the U. S. is not staggering (about

10 million gallons per year), the nature of this waste makes disposal a difficult problem, from which all re-refiners would welcome relief. An unknown but probably lesser quantity of acid sludge is also generated in the treatment of industrial waste oils.

Only one re-refiner is still using lagoons for acid sludge, and obviously this is only a temporary solution. At least two other re-refiners have lagoons containing acid sludge and other residues from earlier operations. The danger in this type of storage is illustrated by an incident where a re-refiner had his lagoons overflow during a hurricane several years ago, causing a major discharge of contaminated oily materials to the nearby river. After lagooning, it is extremely expensive to find a method of disposing of the millions of gallons of sludges stored in this way. Chemical petroleum, and steel companies have had similar problems.

Landfilling of acid sludge, the most common disposal method, appears to be a reasonable, though not ideal method of disposal, provided sufficient safeguards protect personnel, ground water, and nearby streams. The sludge is often mixed with refuse at the landfill site. California has designated a "number one landfill" suitable for acid sludge and other oil and chemical disposal. Few other states have followed suite.

The soluble free-acid probably leaches through the soil, and in alkaline soil is finally converted to sulfate salts,entering the ground water or nearby streams. Some other sulfates in the sludge probably end up the same way (see Table 19 for sulfate solubilities), but lead, barium, calcium, silver, arsenic, molybdenum, titanium, strontium, and other heavy metal salts may remain in the landfill. The concentrations are low, and should not be a serious problem, although future use as a growing area may present some danger. This is illustrated by experience with the use of sewage sludge containing metals from industrial sources as a fertilizer, where repeated applications markedly increased soils chromium, lead, copper, zinc, mercury, and cadmium contents.[59] However, these metals may or may not be transferred to vegetation.[60]

Work done by Shell Oil under an EPA grant[61] indicated that soil micro-organisms decompose petroleum oily waste and that oil and fertilizer chemicals did not penetrate the soil at the location and conditions of the test. However, resi-

Table 20. SULFATE SOLUBILITY[57]
AND ENVIRONMENTAL HAZARDS OF ACID SLUDGE INORGANICS[58]

MAJOR ELEMENTS IN ACID SLUDGE	SOLUBILITY OF SULFATES IN WATER (GRAM/100ml (°C)	COMMENTS ON ENVIRONMENTAL HAZARDS
Cu $CuSO_4$	14.3 (0°) 75.4 (100°)	Copper sulfats causes irritation of skin
Al $Al_2(SO_4)_3$	31.3 (0°) 98.1 (100°)	$Al_2(SO_4)_3$ readily hydrolyzes to sulfuric acid which acts as tissue irritant
$Al_2(SO_4)_3 \cdot 18H_2O$	86.9 (0°) 1104.0 (100°)	
Fe $Fe(SO_4) \cdot 7H_2O$	15.65 (0°) 48.6 (50°)	Ferrous sulfate is used as a nutrient and dietary supplement food additive.
Pb $PbSO_4$ (anglesite)	0.00425 (5°) 0.0056 (40°)	Pb is cummulative poison. It produces brittleness of red blood cells so they homolyze with slight trauma and are destroyed more easily.
$Pb\ SO_4 \cdot PbO$ (lanarkite)		
Zn $ZnSO_4 \cdot 7H_2O$	96.5 (20°) 663.6 (100°)	Zn is not a toxic element for humans, but zinc oxide dust is known to give eczema in men engaged in packing this compound.
Ba $BaSO_4$	0.000222 (18°) 0.000336 (50°) 0.00413 (100°)	$BaSO_4$ is non-toxic. Soluble impurities can lead to toxic reactions. One report describes a fatal case of poisoning due to BaO, with severe abdominal pains, vomiting, dyspnoea, rapid pulse, paralysis of arm and leg.
$BaS_2O_8 \cdot 4H_2O$ (Barium Peroxy disulfate)	52.2 (0°) decomposes in hot water	
Cr $CrSO_4 \cdot 7H_2O$	12.35 (0°) 120.0 (20°)	
Ca $CaSO_4$	0.209 (30°) 0.1619 (100°)	
$CaSO_4 \cdot 2H_2O$	0.241 (?°) 0.222 (100°)	

Table 20. (Continued)

MAJOR ELEMENTS IN ACID SLUDGE	SOLUBILITY OF SULFATES IN WATER (GRAM/100ml (°C)	COMMENTS ON ENVIRONMENTAL HAZARDS
Na		
Na_2SO_4 (anhydrous)	4.76 (0°) 42.7 (100°)	Toxic effects are unknown.
$Na_2SO_4 \cdot 10H_2O$ (Glauber's Salt)	11.0 (0°) 92.7 (30°)	
$Na_2SO_4 \cdot 7H_2O \cdot$	19.5 (0°) 44.0 (20°)	
Mg		
$MgSO_4$	26.0 (0°) 73.8 (100°)	Used as a nutrient and/or dietary supplement food additive.
$MgSO_4 \cdot 7H_2O$	71.0 (20°) 91.0 (40°)	
$MgSO_4 \cdot H_2O$	68.4 (100°)	Inhalation of fumes of sublimed MgO may cause metal fume fever. Particles of Mg metal or alloy which perforate the skin or gain entry through cuts or scratches may produce severe local lesion.

Table 20. (Continued)

ELEMENTS IN ACID SLUDGE PRESENT IN 10 TO 50 PPM CONCN.	SOLUBILITY OF SULFATES IN WATER (GRAM/100ml(°C)	COMMENTS ON ENVIRONMENTAL HAZARDS
Ag		
Ag_2SO_4 (silver sulfate)	0.57 (0°) 1.41 (100°)	Silver sulfate decomposes on heating emitting highly toxic fumes of oxides of sulfur.
Ni		
$NiSO_4$ (Nickel sulfate)	29.3 (0°) 83.7 (100°)	Nickel sulfate is used as food additive
$NiSO_4 \cdot 7H_2O$	75.6 (15.5°) 475.8 (100°)	Nickel and most salts are not considered to cause systemic poisoning. Ingestion of large doses of nickel compounds (1 to 3 mg/kg of wt) has been shown to cause intestinal disorders, convulsions.
$NiSO_4 \cdot 6H_2O$	62.52 (0°) 340.7 (100°)	
Sn		
$SnSO_4$	33 (25°)	
$Sn(SO_4)_2 \cdot 2H_2O$	very soluble in cold water. Decomposes in hot water.	Some tin salts are irritants or can liberate toxic fumes on decomposition. Alkyl tin compds. are highly toxic and produce skin rashes
As		
As_2S_2 (Arsenic Disulfide)	insoluble	Arsenic compounds used as insecticides Arsenic poisoning can be acute or chronic.
As_2S_5 (Arsenic pentasulfide)	0.000136 (0°)	
Mo		
Molybdenum Compounds		Molybdenum compounds are somewhat toxic but in spite of their considerable use, poisoning has yet to be reported.
Mn		
$MnSO_4$	52.0 (5°) 70.0 (70°)	Manganese sulfate is used as a nutrient and food additive. Does not pose any environmental hazard.
$Mn_2(SO_4)_3$	Decomposes in hot water, very soluble in cold water.	
$MnSO_4 \cdot 2H_2O$	85.27 (35°) 106.8 (55°)	
$MnSO_4 \cdot 7H_2O$	172.0 ( ) 118.0 (13°)	
$MnSO_4 \cdot 6H_2O$	147.4 ( )	
$MnSO_4 \cdot 5H_2O$	124 (0°) 142 (54°)	
$MnSO_4 \cdot 4H_2O$	105.3 (0°) 111.2 (54°)	
$MnSO_4 \cdot 3H_2O$	74.22 (5°) 99.31 (57°)	

Table 20. (Continued)

ELEMENTS IN ACID SLUDGE PRESENT IN 10 TO 50 PPM CONCN.	SOLUBILITY OF SULFATES IN WATER (GRAM/100ml(°C)	COMMENTS ON ENVIRONMENTAL HAZARDS
V		
$VSO_4 \cdot 7H_2O$	Decomposes in air; no solubility data reported.	
Vanadyl sulfate (minasragrite) $V_2O_4(SO_3)_3 \cdot 16H_2O$	Very soluble in cold water. Decomposes in hot water.	

Table 20. (Continued)

OTHER ELEMENTS PRESENT IN ACID SLUDGE IN LESS THAN 10 PPM	SOLUBILITY OF SULFATES IN WATER (GRAM/100ml (°C)	COMMENTS ON ENVIRONMENTAL HAZARD
Ti		
$Ti_2(SO_4)_3$ (Titanous Sulfate)	Insoluble in water	Titanium compounds are considered to be physiologically inert.
$TiOSO_4$ (Titanium basic sulfate)	Decomposes in water	
Cd		
$CdSO_4$ (Cadmium Sulfate)	75.5 (0°) 60.8 (100°)	Inhalation of fumes or dusts of cadmium affects respiratory tract and kidneys. High concentration may result in edema and death
$3CdSO_4 \cdot 8H_2O$ (usual commercial form)	114.2 (0°) 127.6 (60°)	
Co		
$Co\ (SO_4)$ (Cobalt Sulfate)	25.6 (0°) 36.2 (20°) 83.0 (100°)	Toxicity of cobalt by mouth is low. It produces dermatitis and hypersensitivity of skin.
$Co(SO_4) \cdot 7H_2O$ (bibeorite)	33.0 (20°)	
$Co(SO_4)_3 \cdot 18H_2O)$	Soluble in water, but decomposes	
Be		
$BeSO_4 \cdot 4H_2O$	42.5 (25°) 100.0 (100°)	
Sr		
$SrSO_4$ (Strontium Sulfate, celestite)	0.0113 (0°) 0.0114 (32°)	Strontium exhibits low order of toxicity

dual naphthenic acids and polyaromatic oils, and rain runoff waters containing 30-100 ppm oil, dictate against indiscriminate use of soil cultivation for disposal of even neutralized sludge. Field tests are underway on oil and machine coolant waste disposal into soil by Union Carbide and Stanford Research Institute.[62] Other companies are known to be using soil cultivation techniques, but technical data is not available.

German work reportedly shows that acid sludge carefully disposed of does not present serious environmental problems.[20] On the other hand, one poorly designed landfill (dump) in the U. S. later experienced "acid oozing" when a foundation was laid on the completed fill.[63]

The acidity, combustible content, metal content, and complex organic content make it imperative that acid sludge not be indiscriminately disposed of. It is a prime candidate for disposal in a regional hazardous waste disposal center as suggested by EPA, although properly designed and operated landfills can accept it with caution. Solidification processes, now practiced on a number of hazardous wastes,[64] provides a possible improvement over untreated disposal, but it is expensive. These are believed to be based on exothermic reactions, such as acid neutralization, driving off water and forming low solubility salts.

Combustion or incineration, even after neutralization, as is done in Europe, is undesirable due to the major amounts of sulfur oxides and very fine metal containing particulates which would be emitted.

Ocean disposal, now generally prohibited in all but the most extreme cases, would probably not be permitted, although existing data is certainly not conclusive. A study of ocean disposal done for EPA considered industrial wastes such as spent sulfuric acid, chlorinated hydrocarbons, drill cuttings and drilling muds, and waste oils.[65] Although some negative data was found, the authors note that "this minute body of information is totally disproportionate with both the amounts of wastes handled and the potential damage that these wastes can do."

As for other methods of acid sludge disposal, deep wells may be suitable in certain instances, but expensive and difficult to prove as environmentally sound. Municipal wastewater treatment plants would most likely not accept this waste without major pretreatment, e.g. dilution with large quantities of water, neutralization, and oil removal.

Acid sludge from one re-refiner is being neutralized with limestone flyash from a steel mill kiln.[64] Acid sludge from another re-refiner is believed to be undergoing similar treatment. In Europe, acid sludge is often mixed with spent clay and/or caustic for neutralization. Neutralization does appear to be desirable, but the cost is significant and care must be taken because of heat release. Some acid sludge is being used in asphalt roofing.

Spent Clay

Spent clay does not appear to present any significant disposal problem. As an absorbent, the clay should retain the contaminants quite well. One would expect the oil to be gradually consumed by bacteria in the soil when clay is disposed of in landfills. Only about 14,000 tons per year of clay are disposed of by re-refiners, though industrial disposal of spent clay used in oil reclaiming may be larger than this figure.

Other Solid and Semi-Solid Wastes

Most other solid and semi-solid wastes resulting from waste oil processing is disposed of on land. Perhaps the most important of these are the oily flocs and sludges which result from wastewater treatment. Others include tank cleaning residues, caustic sludges, filter and centrifuge solids, etc.

The uncertainties of environmental effects due to landfill has already been discussed. The other major approach to disposal of oil-containing solids and semi-solids is incineration. For pumpable wastes, this is accomplished with special thermal incinerators, empty refractory chambers equipped with waste liquid and auxiliary burners; by combustion in existing steam boiler furnaces; or in the case of offshore well tests, huge open air atomized burners.[66] For primarily solid material, incineration is accomplished in rotary kilns and conventional solid waste incinerators, often mixed with other solid wastes. Fluidized bed incinerators are now being used for refinery wastes, including API separator sludge, air flotation skimming, spent caustic and other liquid wastes,[67] and could also be applied to other oily waste disposal problems.

Incineration has several major disadvantages. The first is that fuel value is lost for high heating value wastes, unless expensive heat recovery facilities are included. For low solids concentrations, auxiliary fuel must be added to support combustion. Finally, incineration of wastes high in ash invariably requires expensive air pollution control equipment to meet present day standards.

The soil cultivation approach to waste disposal has already been discussed. Biological degradation of waste oil sludges has also been demonstrated in a laboratory reactor.[60]

Distillation and Extraction Bottoms

Distillation or extraction bottoms contain from about 5-30% ash, more than one-half of which may be lead compounds when running automotive drain oil. At least two plants in the U. S. now use such fractions for asphalt blending; one plant in Europe uses a similar material as a fuel, but heat exchanger tube fouling and presumably high particulate air emissions result.[20] Lagoons have also been used for disposal, but these suffer from the difficulties previously discussed.

Distillation or extraction bottoms provide an excellent possibility as a fuel source in secondary lead smelting reverberatory furnaces which are equipped with fine dust collection equipment. Test burning in such a furnace is planned in the near future under an EPA grant to NL Industries. The geography of such a scheme appears to be good, with many furnaces located across the country (to reprocess lead from batteries and other scrap). Both fuel and lead values are expected to be recovered.

Wastewaters

Distillation condenser water and other waste oil processing wastewaters may contain phenols. Wastewater characterization data obtained by the contractor, including phenol analyses, were provided earlier in this section. Additional data is being obtained by NORCO as part of an EPA project. Use of surface condensers should be considered to minimize the water volume. Phenols can be removed by oxidation, including bio-oxidation, adsorption, or extraction. Water that is discharged directly to rivers and other streams results in environmental problems similar to that from any petroleum refining operation, as discussed in EPA's preliminary report to Congress.[43]

In the re-refining facilities visited, only a few allowed oily rain water to run off to streams. Runoff was treated with process water by separators. It was reported that most re-refiners were able to meet local regulations for discharge to municipal sewers, but it is doubtful whether any could meet new Federal guidelines for discharge to surface waters.

Water discharged to municipal sewage plants normally must contain less than 100 ppm oil. A laboratory study has shown that for conventional plant operations, the influent to an activated sludge system should contain less than 75 ppm hexane extractables, and preferably less than 50 ppm, because of adverse effects on sludge settling properties.[69] The oily materials introduced, including crankcase waste oil, were absorbed almost immediately onto the biological floc. In general, shock loads up to 5% of the sludge weight under aeration was acceptable, while a 10% load caused significant upset in the system.

Air Emissions

Loss of volatiles and vapors is usually reduced by closing tanks, applying a slight vacuum to equipment, venting to furnaces, and in severe situations, installation of scrubbers, absorbers, or other suitable air pollution control systems.

Burning of lead or other metal containing wastes creates potential air pollution problems (in the form of fine particulates[29]), and should not be done indiscriminately. Even though air quality standards for lead have not been promulgated, the uncertainty and controversy surrounding the issue indicates that unnecessary emissions should be at least discouraged or controlled; particularly since lead recovery and burning in lead furnaces seem feasible. Numerous references on this subject are available.[70-78]

OVERALL ASSESSMENT AND FUTURE CONSIDERATIONS

Acid sludge disposal is the most serious of the re-refining waste disposal problems. Although acid sludge presents serious handling problems, these can be overcome with care. However, due to the contents of lead and other metals, combustibles, and oil, disposal in lagoons, pits, or by any indiscriminate means, poses serious hazards. Mixing with refuse and/or neutralization and spreading in well designed and operated landfills experienced in receiving hazardous wastes seems reasonable, at least as a short term solution.

Loss of lead to the land in the quantities now encountered appears to pose no major environmental threat, but obviously is not desirable from the point of view of resource conservation, since U. S. lead supplies are limited. Even though lead content of automotive drain oils will decrease as gasoline lead limitations take effect, it would be very desirable, as soon as possible, to eliminate the acid treating step which generates acid sludge.

Disposal of spent clay to a well designed landfill does not appear to be a serious problem, although additional data on spent clay composition, including the possible presence of carcinogens, and on the rate of oil degradation is very desirable. Other known waste products from re-refining and waste oil processing are also not considered to be serious threats to the environment.

Undesirable air and water emissions from re-refining operations have been reduced considerably in recent years. Additional controls as necessary can be instituted if adequate financing and good management and engineering support are available.

Oily flocs and sludges from wastewater treatment in such industries as petroleum, petrochemicals, iron and steel, metal fabrication, pulp and paper, foods, and others, are a serious problem, at least in terms of volume and poorly understood environmental effects. There is a need for considerable investigation in this area.

On the whole, the environmental effect of waste products and residues from waste oil processing appears to be much less of a problem than would exist from waste oils if no reclaiming were practiced. The reclaiming business should be encouraged to insure that sufficient capacity is available to receive and adequately process waste oils for secondary use, and aided in overcoming the waste disposal problems which do exist.

SECTION IX

WASTE OIL SURVEYS

Three separate surveys were conducted with varying purposes. In the first, a general survey of the Pittsburgh area was designed to test survey methodology and to obtain preliminary waste oil generation data from a major metropolitan area. As will be shown, the test of methodology showed that such surveys are not accurate. Therefore, the national survey which had been contemplated was abandoned in favor of a survey of waste oil collectors and processors.

The third survey was designed primarily to obtain technical information from leading industrial companies on their waste oil practices.

PITTSBURGH AREA

The survey portion of this study had two distinct, although overlapping objectives. The first was to consider the recycling of waste oil in one major metropolitan area. We were interested in both the current state of waste oil recycling, and in trends with implications for the future. The results, wherever possible, were to be quantitative in nature. Ideally, they would be projectable to the entire metropolitan area studied.

The second purpose was to use the sample area as a pilot study for a potential nationwide project. Here the emphasis was on developing understanding and testing techniques.

Some of the results, and in particular, some key facts for service stations are projectable. Some results are less quantitative, since they were based on openly-structured interviews, and the respondents themselves did not represent a random sample. This approach was deemed necessary to get a better understanding of the nature and relative magnitudes of the various sources of waste oil.

Area Studied

In accordance with the project requirements, it was necessary to choose one specific metropolitan area for study. The major factors in choosing the specific area are primarily negative. The area chosen had to be:

a) not so large as to be unmanageable within the project budget constraints (e.g. New York or Chicago).

b) not so small as to not have a representative cross-section of oil users.

c) not a one-industry town (e.g. Detroit or Akron).

d) not a part of a larger, contiguous megalopolis (e.g. Newark).

In addition it was desirable for the area to have both a number of major industrial plants and a number of large corporate headquarters. Among the several areas meeting these requirements, Pittsburgh was chosen more or less randomly.

General Discussion

An important consideration in conducting a waste oil survey is to distinguish between quantities of oil used, waste oil generated internally, recycled internally, generated externally, and available for recycle externally. The differences between these five terms are affected by consumption at the point of use, internal recycle facilities, spills, and questions of quality degradation at every step.

An example of significant losses occurs in pipelines which generally have spill tanks at pumping stations. The oil contained in these spill tanks is not (in the Pittsburgh area at least) directly reinserted into the pipeline flow, making this substantial amount of oil available for recycling. Detecting the potential significance of pipeline spillage is one of the results of the use of open-ended interviews.

Depending on usage and user, the proportion of recoverable oil varies from none at all up to 85% or 90%. The lowest proportions are for process oil, and oil added to gasoline for lubrication (primarily vehicular - usually two cycle engines). For other industrial uses the main factor in the proportion of recoverable oil appears to be the degree to which the oil must be contaminated before it is unsuitable for further use. For instance, oil used for some lubrication purposes is often almost totally used up since even fairly contaminated oil remains usable, with new oil being added on a continuing basis. Oil used for electrical insulation,on the other hand, often loses its quality at relatively low contamination levels and can be recovered and recycled either internally or externally.

On the whole, oil used in vehicular and especially automotive crankcases is recoverable in high proportions. Non-recoverable crankcase oil is of two types: oil burnt up by the engine and oil left in the oil filter. This latter can be of considerable significance. If the oil filter is changed every other oil change, about 8-10% of automotive lube oils could be discarded with filters.

As noted before, waste oil generated by a particular process (i.e., generated internally) is not the same as waste oil available for recycling externally. Whether particular sources of waste oil will produce oil available for recycling outside the generating source depends upon several factors, the most important being the following:

> How much waste oil is produced at a particular point. Paradoxically, the greater the quantity of waste oil produced, the less likely it is that the oil is available for external recycling. This is because large quantities at a single place make it economic for the organization generating the oil to find uses for it themselves (e.g. burning).
>
> How much heat or power generation is done by the waste oil generating organization. An organization buying substantial amounts of heating oil will have obvious reasons and potentialities for using its own waste oil as fuel.

A corollary is the necessity to distinguish the quality of waste oil generated. Clean oil overflowed into a spill tank is obviously not in the same condition as oil taken from a truck engine after 6,000 miles. While general statements are difficult, many industrial uses seem to be at the two extremes. For instance, most insulation and hydraulic uses, and some lubrication uses, lead to a quality of oil equivalent to simple spillage as a source of waste, while some process uses such as rubber compounding change the basic nature of the oil. There is, or course, significant lubrication use,which is similar to vehicle use in the poor quality of the waste oil that is produced.

Finally, we found that the waste oil recovery process seems to be going through a period of considerable upheaval. Underlying the changes are the major recent, current,and presumably near-term future changes in the economics of the problem. One example is that the value of oil as a fuel has produced substantial changes in the use of oil directly at the point of collection by industrial users. A major utility, for example, has just recently switched to burning its used electrical insulation oil in its steam generators, and will shortly do the same with crankcase oil collected from its fleet of almost 1,000 vehicles. Similarly, as oil becomes more valuable (and continues in short supply), the economics of collection clearly change for the recycler. On the other side, the growing environmental pressure leads to greater concern for recycling wastes of all types.

Summary

Overall, we found that in the Pittsburgh area most (although not all) recoverable waste oil is being recovered; that the recovery process, especially for industrial wastes, is more and more becoming a process carried out internally for a particular organization; and that the availability of waste oil for recycling must be understood in terms of not only how much, but what types, where and how. The elaboration of these findings for each source of waste oil is presented in Appendix C.

The work performed and the results obtained in the survey can be summarized as follows.

General - All waste oil is not available for external recycling. Aside from those purposes which use up all or most of the oil, substantial amounts of waste oil are, especially in industry, internally recycled or used at the source for fuel, road oil, etc. The proportion of waste oil being internally recycled or reused in industry is rising, and the oil shortage should accelerate this rise.

The most significant sources of external recycled waste oil in the Pittsburgh area are automotive crankcase oil and oil spilled in pipeline transportation.

Most waste oil in the Pittsburgh area which is potentially recyclable appears to be presently recycled, but for uses other than lube oils, including fuel use. This is partly a result of the fact that there are no re-refiners (producing lube oils) within 230 miles of Pittsburgh.

Private Vehicles - A random sample survey of 100 service station owners and/or managers was carried out in the Pittsburgh area. A total of 83 interviews was successfully completed.

The service station respondents turned out to be unable to give consistent information on the amount of waste oil they collect from automotive crankcases. Asked about waste oil in three ways (oil sold for changes, number of changes, and total collected) they provided substantially differing information.

On an average basis we estimate that there is about 1,100 gallons of waste oil generated per service station per year in the Pittsburgh area.

New car dealers and maintenance centers appear to generate roughly half as much waste oil as do service stations.

We estimate that in Pittsburgh about 2.3 million gallons ± 33% is the total waste oil generated from privately owned automobiles per year.

Other Sources - There are five main categories of organizationally owned vehicles: rental fleets, for-hire trucking, fleets owned for direct organizational use, automotive public transportation, and non-automotive vehicles.

Overall we estimate organizationally owned vehicles generate about half as much available-for-external-recycling waste oil as do private vehicles, or about 1.4 million gallons per year.

There are five main classes of non-vehicular oil usage. Ranked in order of recoverable waste oil in Pittsburgh, these are: oil spilled and contaminated in transit (pipelines), insulation oil, process uses, and lubrication.

Based on population ratio from national figures, one would estimate about 10 million gallons of industrial oil sold in the Pittsburgh area per year. Because of the industrial nature of the area this could be as high as 15 million gallons per year. About one million gallons appears to be available for recycling at locations other than those of the original users.

Collector Survey - Interviews were carried out with six waste oil collectors in the Pittsburgh area. Of these, three turned out to be collectors who merely deliver the waste oil to the processing plant of the one large operation.

From interviews with collectors we estimate 1973 collection by Pittsburgh-based firms at about 11 million gallons. This breaks down as

About 4.5 to 5.5 million gallons from the Pittsburgh area

About 3.0 to 3.5 million gallons of pipeline spillage from a wide area around Pittsburgh

About 3.0 to 3.5 million gallons from other than pipeline spillage from areas outside Pittsburgh (e.g. West Virginia, Ohio).

Overall Results - The total crankcase waste oil is estimated at about 2.7 to 4.8 million gallons with a best estimate of about 3.7 million gallons. About one million gallons per year of industrial waste oil is estimated to be available for recycling.

About 9 million gallons of automotive oil are estimated to be sold in the Pittsburgh area per year. About 5 million gallons should be available for recycling based on the estimates made in Section X. This compares with the estimate of about 3.7 million from the survey.

A National Study

It was the original expectation of the Request for Proposal which initiated this study that one result would be a proposal for a comprehensive national study of the potential for oil recycling. As a result of the data collection problems discussed above, especially in the service station area, we have come to the conclusion that a national study would be of limited value, if any, unless accompanied by a continual record-keeping system for a large national sample.

This approach seems impractical because of cost, which probably would exceed the value of more accurate survey results.

Thus, only a limited version of a national study was recommended, concentrating on a study of collectors and processors to obtain accurate current data.

For completeness, the sample which would be proposed in a national study, if there were no question of data collection problems, appears as Table 21.

WASTE OIL COLLECTORS AND PROCESSORS

The overall goal of this survey was to provide data on the waste oil industry in the U. S. More specifically, the study has attempted to: (1) assess industry size; (2) determine industry practices; (3) analyze current and future industry trends; and (4)provide national estimates. Some of the results are presented below. Details are provided in Appendix D.

Method

This study employed telephone interviews with responsible executives in waste oil collector and collector/processor firms as the basic data gathering approach. One hundred such firms were interviewed in April of 1974.

Response Analysis,the subcontractor, initially developed a listing of waste oil firms from a variety of sources: telephone directory yellow pages, lists of licensed firms in states where such firms must be registered, and from information supplied by several governmental agencies and industry associations.

The Response Analysis national probability sample, with 103 primary sampling units throughout the United States, was the basis for selecting particular waste oil firms. This sampling method provides an accurate basis for making national estimates, within certain statistical limitations. Data on waste oil firms in this study was weighted up to provide national estimates of the industry for several key items.

Characteristics of the Waste Oil Industry

Nationwide, fewer than 500 firms appear to operate in the waste oil industry. Of these, approximately 60% are

Table 21. NATIONAL SAMPLE STRUCTURE

Category	Sample Basis	Number of Interviews	Remarks
SERVICE STATIONS			
Regular	National probability	750	
Highway stations	National probability	100	
Truck stops	National probability	100	
OTHER PERSONAL AUTO SERVICING			
New Car	National probability	100	
Auto repair	National probability	100	
Department/discount	National probability	100	
FLEET AUTOMOBILES			
Government	National probability	100	
Public transportation	National probability	100	½ taxis;½ other
Utilities (cars,trucks)	National probability	50	
Distribution firms-light trucks	National probability	100	½ truckers; ½ commercial
Auto rental	National probability	100	
Industrial	Fortume 1250	100	Some stratifica- by broad industry type
Trucking firms-heavy trucks	National probability	100	
NON-AUTOMOTIVE USES			
Airlines	Fortume 1250	25	Interviews at maintenance headquarters
Pipelines	Standard & Poor	25	
Airports for general aviation	National probability	25	
General industrial	Standard & Poor	200	Substantial stratification by industry type
Railroads	Fortume 1250	25	
SALES ONLY (Telephone Interviews)	National probability	600	Total of 600, including those done in category under department/discount to establish servicing areas

collectors and 40% are collector/processors.

The waste oil industry is highly fragmented, ephemeral, and not easily characterized in terms of the "average" operator or firm. During the past year many new firms were started, although many will probably go out of business quickly, or move operations to another city or state. Older firms may also change hands, particularly in the current highly competitive situation. Many older firms also appear to change their place of business and market areas at frequent intervals. Many firms, both old and new, seem to run their businesses in a highly informal and flexible manner, often operating out of temporary facilities with no formal address or phone number. Under these circumstances, any form of regulation is difficult.

Collectors tend to search for waste oil sources on an informal basis without contracts or a specified callback system. Collector/processors, however, do sometimes collect under contractual agreement. There is also evidence to suggest that much of the waste oil initially collected is immediately disposed of. This alternative may still be more economical than transporting the waste oil to a processing plant.

Some waste oil executives perceive little or no need for air and water pollution control measures in their industry. Many spokesmen seem defensive when asked whether or not their type of industry produces any form of pollution. The majority of companies dispose of processing wastes in landfills.

Trends in the Waste Oil Industry

Future industry growth will probably be experienced by the collector/processors at the expense of the collectors. At present, more collector/processors say they are experiencing growth than collectors. (When asked to predict future trends in the industry, many more collector/processors were optimistic about future growth than were collectors.)

The waste oil industry seems to be at the mercy of many external factors, affecting business in both the short and long run. Recent shortages in petroleum have been a mixed blessing. While more oil is needed for the domestic market (including reprocessed waste oil) less oil is available because people are driving less and no longer require frequent oil changes. Automobile and truck manufacturers have also extended the recommended intervals between oil changes, thus reducing available waste oil even further. All of these factors contribute to operation below the industry's capacity.

Concern over environmental problems, government regulation, licensing, and inspection play both a direct and indirect role in determining practices in the waste oil industry, including "acceptable" methods for handling waste materials. All of these factors have a negative effect on the availability of capital for investing in new state-of-the-art equipment for processing waste oils.

Background Impressions

Waste oil firms,in general, keep either poor records or no records. Some are even reluctant to attempt estimates. This is more true of collectors--collector/processors operate larger, more formalized businesses and tend to have more complete records.

Collectors and collector/processors are not cooperative respondents. Many refused to grant an interview, and many of those who did refused to answer many of the questions.

To date, the waste oil industry has been relatively unknown, unrecognized, and unmeasured. In general, there appears to be little information from any source (including state and federal agencies) on firms in the waste oil industry. While this report discusses most phases of the industry, many questions about further aspects of waste oil collection and processing are also raised.

Data Summary

Some of the more important results of the survey are presented in Tables 22-24. A summary of national estimates is provided in Table 25.

It is apparent from Table 22 that the industry is dominated by companies who do processing. However, because of the large quantity of oil reported collected, but not accounted for ("Other or Not Reported"), even these companies may be bypassing processing and transferring oil directly from collection to fuel, road oil, dust control, and perhaps landfill or other questionable practices.

Table 23 provides some insight into the type of processes used. It is apparent from these figures that most

Table 22. WASTE OIL COLLECTION AND USE

	Collectors		Collector/ Processors		
	No.	Gal/Month	No.	Gal/Month	
Collection					
Total Waste Oil Collected	61	3,531,000	39*	19,114,000	
Collected From Other Collectors	8	32,000	16	3,850,000	
Net Collected		3,499,000		15,264,000	
Collected From Service Stations and New Car Dealers		2,030,000	(58%)	2,745,000	(18%)
Uses					
Road Oil or Dust Control	15	57,000	8	43,000	
Fuel	12	75,000	14	300,000	
To Processing	14+	117,000	39	3,775,000	
Other or Not Reported	7	3,282,000	5	14,996,000	
		3,531,000		19,114,000	

* Includes 8 processors who have no collection facilities of their own, but have a working relationship with collectors.

+ Includes simple settling.

Table 23. TREATMENT PROCESSES USED

	% of the 39 Processors Who Use
Filtration or Centrifugation	87
Settling	56
Flash Drying or Distillation	77
Clay Treatment	46
Acid Treatment	44
Caustic, Silicate or Other Chemical Treatment	59
Other	13

plants have multi-step processes, or a choice for each oil processed. Most separate solids and/or water by settling, filtration, or centrifugation and probably dry also by vaporizing water. Acid, clay and chemical treatments seem to be common.

The amount of lube oil produced as compared to other products, shown in Table 24, is high, but the total oil accounted for here (51,000,000 gallons per year) is only 22% of that collected by the processors interviewed (19,114,000 gallons per month), again raising the question of whether much of the collected oil is processed at all.

The subcontractor's projection of the information obtained, shown in Table 25, indicates that there are 423 collectors and processors nationwide who collected 1,640 million gallons of waste oil in 1973, and processed 706 million. These figures may be compared to estimates based on 1970-71 sales volumes and estimated recoveries and losses, as shown in Section X:

	Millions of Gallons Per Year	
	Projections from Survey of Waste Oil Collectors & Processors	Projections from Methods of Section X
Collection	1,640	1,502 (oil processed + oil to fuel + road oils, etc.)
Processed	706	901 (waste oil processors + re-refiners)

This close check for estimates made entirely independently, by very different methods, lends confidence to their validity.

Table 24. TYPES OF OILS PRODUCED BY PROCESSORS

	Gallons Produced In 1973	(%)
Fuels	19,890,000	(39)
Lube Oils	19,890,000	(39)
Road Oil	3,570,000	(7)
Process Oil	4,080,000	(8)
Journal Box Oil	2,040,000	(4)
Asphalt Flox & Other	1,530,000	(3)
	51,000,000*	(100)

* Based on 21 of 39 processors who supplied relevant data.

Table 25. NATIONAL ESTIMATES

Collection	No.	1973 Totals Millions of Gallons
Collectors	260	---
Collector/ Processors	163	---
	423	1,640
Processing*		
Actual Processed	163	706
Capacity	163	1,055

* Including re-refiners.

SURVEY OF INDUSTRIAL FIRMS

One organization in each of fifty-seven SIC (Standard Industrial Classification) major groups were interviewed to investigate the purchase and use of oils, and waste oil generation and disposal. These groups included some governmental and institutional organizations, as well as industrial companies.

Visits were made to about one-half of the organizations; information from the remainder came via telephone and mail. Both visit and telephone interviews were nationwide, primarily with leading companies in their fields. Information received was on the basis that the organization contacted would not be identified.

The primary purpose of the survey was to obtain technical information on industrial practices. All interviews were conducted by the Contractor's technical staff who are well versed in waste oil problems. No attempt has been made to handle the data on a statistical basis.

The cooperation received ranged from fully cooperative to complete non-cooperation. In the latter cases, a substitution was made for the original organization selected. Most multi-plant companies had no centralized oil purchase records; very few had centralized records of waste oil generation or disposal. Therefore, in many instances information was gathered from a single location, either typical of the organization, or a plant using a large quantity of oils.

Discussions in other sections of this report reflect information gathered during this survey. The data gathered also tended to reinforce material balance calculations shown in Section X. A summary of the information obtained appears as Appendix E.

Ultimate disposal of waste oils and other oily materials meant pickup by an independent collector in most cases. Only a few companies were aware of the destination of oil which left the company facilities by this route.

A compilation of the number of companies using various disposal methods follows. These are based on 56 answering, with many companies having multiple disposal methods:

Disposal Method	No. of Organizations	% of Organizations Answering
Picked up by collector	38	68
Reclaimed internally or externally for internal use	16	29
Landfill (or dump)	15	27
Used as fuel	14	25
Significant losses to wastewater	9	16
Discarded to trash or refuse	8	14
Road oiling or dust control	4	7
Incineration	2	4

SECTION X

QUANTIFYING U. S. WASTE OIL GENERATION AND DISPOSAL

A waste oil material balance for the U. S. has been attempted. Although major data gaps have been identified, a complete balance has been made, using best estimates to fill these gaps. The data are summarized in Table 26. Details are provided in Appendix F.

Waste oil balances are basically built up from:

- sales data on oil sales in various categories, e.g. automotive lubes, industrial lubes, other industrial oils, etc.
- information obtained during the Contractor's surveys, or previous surveys, on the portion of oil sold which becomes waste oils, or best estimates where such data are lacking.

As already noted in Section IX, the estimate for total waste oil generated in 1970-71, obtained as follows from Table 26:

Disposed of to:	Millions of Gallons Per Year
Waste oil processors	763
Re-Refiners	138
Road Oils, Asphalt, Etc.	243
Fuel	358
	1,502

checks very closely with the estimate of the total quantity collected, 1,640 million gallons per year (1973), obtained from the survey of collectors and processors. The total processed:

Disposed of to:	Millions of Gallons Per Year
Waste Oil Processors	763
Re-Refiners	138
	901

also provides a reasonable check against the survey result of 706 million gallons per year.

TABLE 26. GENERATION AND DESTINATION OF WASTE OIL (W.O.) - MILLIONS OF GALLONS PER YEAR

	Sales	W.O. Factor	W.O.	To W.O. Processors	To Re-Refiners	Road Oils, Asphalts, etc.	For Fuel	To Environment
Automotive Lube Oils								
Service Stations	270	.63	170					
Garages, Auto Supply Stores	60	.63	38					
New Car Dealers	102	.90	92					
Retail Sales for Commercial Engines	90	.63	57					
Auto Fleet & Other Lube Oil Users	136	.50	68					
Factory Fills 'Auto & Farm Equip.)	60	.90	54					
Discount Stores	168	.22	37					
Commercial Engine Fleets	200	.50	100					
	1086		616	202	105	142	19	148
Industrial & Aviation Lube Oils								
Hydraulic & Circulating System Oils	325	.42	137					
Metal Working Oils	150	.70	105					
Railroad Engine Oils	60	.53	32					
Gas Engine Oils	62	.90	56					
Aviation & Other	137	.47	64					
	734		394	130	16	25	111	112
Other Industrial Oils								
Process Oils	310	.10	31					
Electrical Oils	57	.90	51					
Refrigeration Oils	10	.50	5					
	377		87	28	3	6	25	25
Lube Oils Purchased by U. S.	37	.50	18	4	3	4	4	3
Sub-Totals	2234	-	1115	364	127	177	159	288
Other Oil Losses and Spills, from Production, Refining, Trensportation, Marketing, Use	-	-	1365	399	11	66	199	690
GRAND TOTALS	-	-	2480	763	138	243	358	978
Disposition from W.O. Processors				(-763)		76	649	38
Disposition from Re-Refiners					(-55)	-	21	34
ULTIMATE DISPOSAL	-	-	-	-	83*	319	1028	1040

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* Re-Refined Products

SECTION X

REFERENCES

1. Bethea, S. R., D. S. Bosniak, B.E. Claybaugh, and E. L. Mohundro. To Hydrotreat Waste Lube Oil. Hydrocarbon Processing :134-136. September 1973.

2. Study of Waste Oil Disposal Practices in Massachusetts. Commonwealth of Massachusetts, Division of Water Pollution. Contractor - Arthur D. Little, Inc. C-70698. January 1969. 36 pages.

3. Delta Airlines Treatment Plant Handles Chemical and Oily Wastes. Industrial Wastes. 28:27-34, September-October 1973.

4. Industrial Oily Waste Control. American Petroleum Institute and the American Society of Lubrication Engineers, 144 pages. Chapter 8, p. 123-136.

5. Martin, E. J., G. D. Gunty. State of Maryland Waste Oil Recovery and Reuse Program. The Maryland Environmental Service. Contractor - Environmental Quality Systems, Inc. Washington, D. C. EPA 670/2-74-03. U. S. EPA. January 1974. 247 pages.

6. Royal, T. B. Reprocessed Oils. Rubber Age :45-50, February 1973.

7. Sales of Lubricating and Industrial Oils and Greases. Social and Economic Statistics Administration, Bureau of the Census. Washington, D. C. MA-29C (71)-1. U. S. Department of Commerce. 1971. 10 pages.

8. Forster, R. L., et al. Port Collection and Separation Facilities for Oily Wastes. Contractor - Frederic R. Harris, Inc. Washington, D. C. 2-36202. U. S. Department of Commerce, Maritime Administration. 1973. 4 volumes.

9. Salvesen, R. H., A. Beerbower, A. R. Garabrant, M. Lieberman. Research of Oily Wastes, Norfolk Area. Naval Supply Systems Command. Contractor - Esso Research and Engineering Company. GRVS 2 EAD. 72. U. S. Navy. January 1973. 53 pages.

10. Beychok, M. R. Aqueous Wastes From Petroleum and Petrochemical Plants. London, John Wiley and Sons, 1967. 370 pages.

11. U. S. Bureau of the Census, Pocket Data Book USA 1971. Washington, D. C., U. S. Government Printing Office, May 1971. 352 pages.

12. Shreve, N. R. Chemical Process Industries, 3rd edition. New York, McGraw-Hill Book Company, 1967. 887 pages.

13. The Encyclopedia of Chemistry, 3rd edition. New York, New York, Van Nostrand Reinhold Company. 1973. Synthetic Lubricants, pages 644-645.

14. Teknekron Report for EPA to be issued.

15. Waste Oil Recovery Practices - State-of-the-Art (1972). Maryland Environmental Service and U. S. EPA, Contractor Environmental Quality Systems. Washington, D. C. December 1972. 250 pages.

16. Conversion of Crankcase Waste Oil Into Useful Products. U. S. EPA, Contractor - National Oil Recovery Corporation. WPCR Series 15080 DBO. March 1971. 87 pages.

17. Chambers, J. M. Crankcase Oil Refining. U. S. Patent No. 3,173,859. March 16, 1965. 9 pages.

18. Chambers, J. M. and H. A. Hadley. Crankcase Oil Re-Claiming. U. S. Patent No. 3,625,881. December 7, 1971. 9 pages.

19. Bonnifay, P., et al. A New Process for Reclaiming Spent Lubricating Oils. Institut Francais du Petrole (Presented at the National Fuels and Lubricants Mtg. National Petroleum Refiners Association, New York City, Sept. 14-15, 1972). 10 pages.

20. Unpublished notes from Dr. P. B. Lederman, EPA, Edison, New Jersey.

21. Villanova University, Final Progress Report, FWPCA Grant WPD-174-01-67, unpublished.

22. Automotive Crankcase Drainings Can Yield the Base Lubricating Oil. Chemical Engineering :51, May 13, 1974.

23. NORCO report to be published.

24. Putscher, R. E. Study of Re-refining Waste Disposal. Armour Research Foundation of Illinois Institute of Technology. Lyons, Illinois. ARF 3808-5. Association of Petroleum Re-Refiners. January 29, 1960. 32 pages.

25. Study of Problems of Refining Lubricating Oil Drainings. Association of Petroleum Re-Refiners. Contractor - Walter C. McCrone Associates, Inc. Chicago, Illinois. MA1982. May 11, 1971. 17 pages.

26. Weinstein, N. J. et al. A Non-polluting Oil Re-Refining Process. Recon Systems, Inc., Princeton, New Jersey. (Presented at American Institute of Chemical Engineers Worshop "Industrial Process Design for Pollution Control."). Chicago. (October 17-19, 1973). 12 pages.

27. Private communication from Teknekron, Inc., Berkeley, California.

28. Twomey, D. W. Lube Market Getting Tighter. Hydrocarbon Processing :201-204, November 1973.

29. Chappell, G. A. Waste Oil Processing. Division of Water Pollution Control, Water Resources Commission, Commonwealth of Massachusetts. Contractor - Esso Research and Engineering Company. Linden, New Jersey. 72-5. January 1973. 39 pages.

30. Freestone, F. J. Runoff of Oils from Rural Roads Treated to Suppress Dust. Edison Water Quality Research Laboratory. Edison, New Jersey. EPA-R2-054. U. S. EPA. October 1972. 29 pages.

31. 1973 Petrochemical Handbook Issue. Hydrocarbon Processing :128, November 1973.

32. Bennett, I. C., et al. Animal-Feed Protein Made From n-Paraffins. Chemical Engineering :45-47, December 27, 1971.

33. Oil Pollution Removal Handbook. Park Ridge, New Jersey, Noyes Data Corporation, 1973. p. 339-394.

34. Vaughn, S. H. and R. S. McCurdy. Wastewater Treatment at Ford's Windsor Complex. Industrial Wastes. 34:34-40, May/June 1973.

35. Gilde, L. C. Pollution Control in Food Industries. In: Industrial Pollution Control Handbook, Lund, H. F. New York, McGraw-Hill Book Company, 1971. p. 16-15.

36. Beychok, M. R. Wastewater Treatment, State-of-the-Art. Hydrocarbon Processing :109-112, December 1971.

37. Racine, W. J. Plant Designed to Protect the Environment. Hydrocarbon Processing :115-119, March 1972.

38. Thomson, S. J. Data Improves Separator Design. Hydrocarbon Processing :81-83, October 1973.

39. Kirby, T. W. Water Conservation at a Major Refinery-Petrochemical Complex. Water-1973, Bennett, G. F. New York, New York, American Institute of Chemical Engineers, 1974, p. 645-653.

40. Willenbrink, R. Wastewater Reuse and In-Plant Treatment. Water - 1973, Bennett, G. F. New York, New York, American Institute of Chemical Engineers, 1974. p. 671-674.

41. Seng, W. C. Recovery of Fatty Material From Edible Oil Refinery Effluents. U. S. EPA, Contractor - Swift and Company. Washington, D. C. EPA-660/2-73-015. December 1973.

42. Lewis, W. L. Petroleum Industry Challenge-Prevention of Ocean Pollution. Water - 1973, Bennett, G. F. New York, New York, American Institute of Chemical Engineers, 1974. p. 654-666.

43. Waste Oil Study - A Preliminary Report to the Congress. U. S. EPA. Washington, D. C. 93-12. May 1973. 55 pages.

44. Manual on Disposal of Refinery Wastes, Volume VI, Solid Wastes, 1st edition. Washington, D. C., American Petroleum Institute, 1963. 51 pages.

45. Methods for Chemical Analysis of Water and Wastes. National Environmental Research Center, Analytical Quality Control Laboratory. Cincinnati, Ohio. 16020---07/71. U. S. EPA, 1971. 312 pages.

46. Standard Methods for the Examination of Water and Wastewater, 13th edition. Washington, D. C., APHA, AWWA, WPCF, 1971. 874 pages.

47. EPA, Solid Waste Disposal, Proposed Guidelines for Thermal Processing and Land Disposal of Solid Wastes, Volume 38, Number 81, Washington, D. C., Federal Register, April 27, 1973, p. 10544-10553.

48. Report to Congress on Hazardous Waste Disposal. U. S. EPA. Washington, D. C. June 30, 1973. 168 pages.

49. Powell, M. D., et al. Digest of Selected Local Solid Waste Management Ordinances. U. S. EPA, Contractor - National Association of Counties Research Foundation. Washington, D. C. (SW-38c). U. S. EPA. 1972. 376 pages.

50. EPA, Oil Pollution Prevention, Non-Transportation Related On-shore and Off-shore Facilities, Volume 38, Number 237, Washington, D. C., Federal Register, December 11, 1973, p. 34164-34170.

51. New Jersey State Department of Health, Division of Clean Air and Water, Water and Sewage Statutes, Trenton, New Jersey, September 1969, 180 pages.

52. Private communication from the State of New Jersey, Department of Environmental Protection, Division of Water Resources, Trenton, New Jersey.

53. Illinois Pollution Control Board, State of Illinois, Water Pollution Regulations of Illinois, March 7, 1972, 36 pages.

54. Statuatory Authority. U. S. EPA, Washington, D. C. December 1972.

55. EPA, Petroleum Refining Point Source Category, Effluent Limitation Guidelines and New Source Standards, Volume 39, Number 240, Washington, D. C., Federal Register, December 14, 1973, p. 34542-34558.

56. Modern Methods for Acid Sludge Disposal. Oil in Canada :24-27, January 18, 1954.

57. Handbook of Chemistry and Physics, 53rd edition. Chemical Rubber Publishing Company, Cleveland, Ohio. 1973.

58. Sax, N. I. Dangerous Properties of Industrial Materials, Third edition. New York, Reinhold. 1968.

59. Metals from Industrial Waste May Limit Fertilizer Use of Sewage Sludge. Chemical Week :36, April 17, 1974.

60. Ocean Disposal Practices and Effects. (A Report from the President's Water Pollution Control Advisory Board to the U. S. EPA Meeting September 26-29, 1972) 20 pages.

61. Kincannon, C. B. Oily Waste Disposal by Soil Cultivation Process. U. S. EPA. Washington, D. C. EPA-R2-72-110. December 1972. 115 pages.

62. Soil Microorganisms Offer Pollution Solutions. Chemical Engineering :26, November 26, 1973.

63. Private communication.

64. Ford Calls in the Sludge Experts (Reprint). Business Week. June 16, 1973.

65. Smith, D. D. and R. P. Brown. Ocean Disposal of Barge-Delivered Liquid and Solid Wastes from U. S. Coastal Cities. Solid Waste Management Office, Contractor - Applied Oceanography Division, Dillingham Corporation. SW-19c. U. S. EPA. 1971. 119 pages.

66. Burning Waste Oil. Compressed Air Magazine :14-16, November 1973.

67. Flood, G. C. and K. L. Kuncl. Over 370 tpd of Oily Sludge Converted Into Clean Air and Innocuous Landfill. Chemical Processing. September 1973.

68. Fragala, R. et al. Microbiological Treatment of Waste Oil Sludge. Commonwealth of Massachusetts Division of Water Pollution Control, Contractor - Tyco Laboratories. Washington, D. C. C-943. June 3, 1970. 40 pages.

69. Barnhart, E. L. The Impact of Oily Materials on Activated Sludge Systems. American Petroleum Institute. Contractor - Hydroscience, Inc. Washington, D. C. 12050 DSH 03/71. March 1971. 110 pages.

70. Lead and Air Pollution: A Bibliography With Abstracts. U. S. EPA, Office of Air Quality Planning and Standards. North Carolina. EPA-450/1-74-001. January 1974. 431 pages.

71. Haley, T. J. A Review of the Toxicology of Lead. Air Quality Monograph, American Petroleum Institute. Washington, D. C. 69-7.

72. Smith, R. G. Air Quality Standards for Lead. Air Quality Monograph, American Petroleum Institute. Washington, D. C. 69-11.

73. Schroeder, H. A. Barium. Air Quality Monograph, American Petroleum Institute. Washington, D. C. 70-12.

74. Schroeder, H. A. Vanadium. Air Quality Monograph, American Petroleum Institute. Washington, D. C. 70-13.

75. Schroeder, H. A. Nickel. Air Quality Monograph, American Petroleum Institute. Washington, D. C. 70-14.

76. Schroeder, H. A. Chromium. Air Quality Mongraph, American Petroleum Institute. Washington, D. C. 70-15.

77. Schroeder, H. A. Cadium, Zinc and Mercury. Air Quality Monograph, American Petroleum Institute. Washington, D. C. 70-16.

78. Schroeder, H. A. Manganese. Air Quality Monograph, American Petroleum Institute. Washington, D. C. 70-17.

79. Miller, N. H. Modern Lubrication Practices - How Lubricants Work. Chemical Engineering:155-162, February 26, 1968.

80. Unpublished study prepared for U.S. Department of Transportation by Jack Fausett Associates. May 1973.

81. Occupational Safety and Health Administration, Department of Labor: Occupational Safety and Health Standards; National Concensus Standards and Established Federal Standards. Federal Register, Volume 36, No. 105, Part II, May 29, 1971.

82. Sax, N. I. Dangerous Properties of Industrial Materials. Third Edition. Reinhold Book Corp., New York. 1968.

83. Manufacturing Chemists Association, Washington, D. C.:
    Chemical Safety Data Sheet SD-9, Caustic Soda
    Chemical Safety Data Sheet SD-20, Sulfuric Acid
    Chemical Safety Data Sheet SD-8, Ammonia
    Chemical Safety Data Sheet SD-64, Lead Oxides

84. Christensen, H. E. (Editor). The Toxic Substances List. 1972 Edition. National Institute for Occupational Safety and Health. Rockville, Maryland. June 1972. 563 pages.

85. Ellis, E. G. Lubricants: An Industrial Health Hazard? Industrial Lubrication 19(4):141-5, 1967.

86. Crude Petroleum and Petroleum Products. Minerals Yearbook. U. S. Bureau of Mines. Washington, D. C. 1971. Page 855.

87. National Petroleum News. McGraw-Hill, Inc. New York. August 1971. p. 54.

88. Oil Spill Technology Takes Big Step Forward. Chemical and Engineering News. April 1973.

SECTION XI

APPENDICES

APPENDIX A

WASTE OIL RE-REFINERS AND PROCESSORS

ARKANSAS

Henley Oil Company
P.O. Box 141
Norphlet, Arkansas 71759

Telephone: 501-546-2582
Contact: Charles W. Henley
Visit Date: None Planned

CALIFORNIA

X Bayside Oil Corporation
977 Bransten Road
San Carlos, Calif. 94070

Telephone: 415-593-2944
Contact: A. Ray Banks
Visit Date: 7/18/73
Visit By: N.J. Weinstein
(with Teknekron)

X Leach Oil Company, Inc.
625 East Compton Blvd.
Compton, Calif. 90220

Telephone: 213-323-0116
Contact: George Leach
Visit Date: 7/20/73
Visit By: N.J. Weinstein
(with Teknekron)

C.S. McAuley, Inc.
P.O. Box 219
Downey, California 90241

Telephone:213-869-1179
Contact: C.S. McAuley
Visit Date: 7/20/73
Visit By: N.J. Weinstein
(with Teknekron)

X Motor Guard Lubricants Co.
4334 East Washington Blvd.
Los Angeles, Calif. 90023

Telephone: 213-268-6877
Contact: H.B. Millard
Visit Date: 7/19/73
Visit By: N.J. Weinstein
(with Teknekron)

Fabian Oil Refining Co.
4200 Alameda Avenue
Oakland, Calif. 94601

Telephone: 415-532-5051
Contact: Bryan Fabian
Visit Date: 7/18/73
Visit By: N.J. Weinstein
(with Teknekron)

X Talley Bros. Inc.
2007 Laura Avenue
Huntington Park, Calif.90255

Telephone: 213-587-1217
Contact: A.W. Talley
Visit Date: 7/23/73
Visit By: N.J. Weinstein
(with Teknekron)

Nelco Oil Refining Company
1211 McKinley Avenue
National City, Calif. 92050

Telephone: 714-474-7511
Contact: Otis F. Humphrey
Visit Date: 7/23/73
Visit By: N.J. Weinstein
(with Teknekron)

COLORADO

X **Williams Refining Company**
5901 North Federal St.
Denver, Colorade 80221

Telephone: 303-433-2497
Contact: Lloyd Cunningham
Visit Date: None planned

FLORIDA

X **Davis Oil Company**
Box 1303, 1100 Orange Ave.
Tallahassee, Fla. 32302

Telephone: 904-576-3116
Contact: George Davis
Visit Date: 8/1/73
Visited By: A.T. Goding

Peak Oil Company
Route 3, Box 24
Tampa, Floriad 33619

Telephone: 813-626-9116
Contact: John Schroter
Visit Date: 7/31/73
Visited By. A.T. Goding

Petroleum Products Co.
Box 336, South Park Road
Pembroke Park
Hallendale, Florida 33009

Telephone: 305-989-4000
Contact: Sol Blair
Visit Date: 7/31/73
Visited By: A.T. Goding

Seaboard Oil Industries of Florida, Inc.
Box 6336
Jacksonville, Florida

Telephone: 904-389-8845
Contact: Byron Cohen
Visit Date: None planned to this plant; see Georgia plant

GEORGIA

Seaboard Industries
Box 47333
5810 New Peachtree Road
Doraville, Georgia 30040

Telephone: 404-458-2241
Contact: Byron Cohen
Visit Date: 8/2/73
Visited By: A.T. Goding

ILLINOIS

X **Motor Oils Refining Co.**
7601 West 47th Street
Lyons, Illinois 60534

Telephone: 312-242-2306
Contact: Benton Williams
R.E. Poindexter
Visit Date: 8/13/73
Visited By: N.J. Weinstein
(with Teknekron)

INDIANA

X **Westville Oil & Mfg. Inc.**
Box 587, State Road #2
Westville, Ind. 46391

Telephone: 219-785-2534
Contact: Andrew Carson
Visit Date: 8/14/73
Visited By: N.J. Weinstein
(with Teknekron)

KANSAS

Coral Refining Company
765 Pawnee Avenue
Kansas City, Kansas 66105

Telephone: 913-281-5454
Contact: Robert O'Blasny
Visit Date: 8/7/73
Visited By: C. Rai

MICHIGAN

X Dearborn Refining Company
3901 Wyoming Avenue
Dearborn, Michigan 48120

Telephone: 313-VI-3-1700
Contact: Jack W. Epstein
B Horton
Visit Date: 7/31/73
Visited By: N.J. Weinstein

MINNESOTA

X Warden Oil Company
187 Humboldt Avenue North
Minneapolis, Minn. 55405

Telephone: 612-374-1200
Contact: A. L. Warden
Visit Date: 7/30/73
Visited N.J. Weinstein

Gopher State Oil Co.
2500 Delaware St. SE
Minneapolis, Minn. 55405

Telephone: 612-331-5936
Contact: C.H. Romness
Visit Date: None planned

MISSISSIPPI

X Jackson Oil Products Co.
Box 5686
Jackson, Miss. 39208

Telephone: 601-939-3131
Contact: H.K. Robertson
Visit Date: None Planned

MISSOURI

X Midwest Oil Refining Co.
1900 Walton Road
St. Louis, Mo. 63114

Telephone: 314-427-2662
Contact: Glen Gettinger
Visit Date: 7/23/73
Visited By: A.T. Goding

NEBRASKA

Monarch Oil Company
Box 1257
22nd Street & Avenue H East
East Omaha, Nebraska 68101

Telephone: 402-341-5254
Contact: Marvin Walenz
Visit Date: None planned

NEW JERSEY

Diamond Head Oil Refining Co.
1427 Harrison Tnpk.
Kearney, New Jersey 07032

Telephone: 201-991-5800
Contact: Martin Morrison
Visit Date: 8/17/73
Visited By: C. Rai

X National Oil Recovery Corp
Box 338
Bayonne, New Jersey

Telephone: 201-437-7300
Contact: Solfred Maizus
Visit Date: 7/12/73
Visit By: N.J. Weinstein
C. Rai, A.T. Goding

NEW YORK

George T. Booth & Son, Inc.
76 Robinson Street
North Tonawanda, N.Y. 14120

Telephone: 716-693-0861
Contact: George T. Booth
Visit Date: 7/23/73
Visited By: A.T. Goding

Northeast Oil Company
327 Edward Drive
Fayetteville, N.Y.

Telephone: 315-454-4180
Contact: R.W. Mahler
Visit Date: None planned

Newtown Refining Corp.
37-80 Review Avenue
Long Island City, N.Y. 11101

Telephone: 212-RA9-7660
Contact: R.W. Mahler
Visit Date: None planned

NORTH CAROLINA

Seaboard Industries, Inc.
South Oil Division
Box 106, Old Burlington Road
Greensboro, N.C. 27402

Telephone: 919-375-5811
Contact: Byron Cohen
Visit Date: None planned
See Georgia

OHIO

Research Oil Refining Company
3680 Valley Road
Cleveland, Ohio 44109

Telephone: 216-749-2777
Contact: Jac Fallenberg
Alan Gressel
Visit Date: None planned
(recent fire)

X Keenan Oil Company
#1 Parkway Drive
Cincinnati, Ohio 45212

Telephone: 513-631-2900
Contact: S.R. Passell
Visit Date: None planned

OKLAHOMA

X Double Eagle Refining Co.
Box 11257
Oklahoma City, Okla. 73111

Telephone: 405-232-0244
(plant):405-232-6878
Contact: Frank Kerran
Cameron L. Kerran
Visit Date: 8/8/73
Visited By: C. Rai

OREGON

Nu-Way Oil Company
7039 NE 46th Avenue
Portland, Oregon 97218

Telephone: 503-281-9375
Contact: A.L. Geary
Visit Date: 7/24/73 (at
Ager & Davis Refining Co)
Visited By: N.J. Weinstein
(with Teknekron)

Ager & Davis Refining Co.
9901 NE 33rd Street
Portland, Oregon 97211

Telephone: 503-288-3584
Contact: Harold W. Ager, Jr.
Visit Date: 7/24/73
Visited By: N.J. Weinstein
(with Teknekron)

PENNSYLVANIA

Berks Associates, Inc.
Box 617
Pottstown, Pa. 19464

Telephone: 215-385-3031
Contact: Lester Schurr
Visit Date: 7/11/73
Visited By: N.J. Weinstein,
C. Rai, A.T. Goding

Petrocan Corporation
P.O. Box 547
Valley Forge, Pa. 19481

Telephone: 215-383-5262
Contact: John Cunningham
Visit Date: 8/17/73
Visited By: A.T. Goding
(with P.B. Lederman)

TENNESSEE

X Gurley Oil Company
Box 2326
Memphis, Tennessee 38102

Telephone:901-527-9940
Contact: William M Gurley
Visit Date: 8/7/73
Visited By: C. Rai

TEXAS

S&R Oil Company
Box 35516
Houston, Texas 77035

Telephone: 713-729-8740
Contact: R.A. Swasey
Visit Date: 8/9/73
Visited By C. Rai

Capital Supply & Refining Co.
Box 597
1401 West Hurst Blvd.
Hurst, Texas 76053

Contact: Abel Theriot
Visit Date: None planned

Texas American Oil
300 Westwall, Suite 1012
Midland, Texas 79701

Telephone: 915-683-4811
Contact: William F. Judd
Visit Date: 8/9/73
Visited By: C. Rai

UTAH

X Alco Refining Company
133 North First West
Salt Lake City, Utah 84113
Contact: J.R. Mastelotto
Visit Date: None planned

VIRGINIA

A.C. Oil Company
1500 North Quincy St.
Arlington, Va. 22207

Contact: V.T. Worthington
Visit Date: None planned

WISCONSIN

Warden Refining Company
1910 South 73rd
W. Allis, Wisconsin 53214

Telephone: 414-541-1000
Contact: M.A. Warden
Visit Date: 8/14/73
Visited By: N.J. Weinstein
(with Teknekron)

WASHINGTON

QED Corporation
P.O. Box 1004
Renton, Washington 98055

Telephone: 206-271-1540
Contact: William S. Kemp
Visit Date: 7/16/73
Visited By: J. Weinstein
(with P.B. Lederman)

"X" indicates Members of Association of Petroleum Re-Refiners.

APPENDIX B

LUBRICATING OIL ADDITIVES

LUBRICANT ADDITIVES *

TYPE	REASON FOR USE	HOW THEY WORK	ADVERSE EFFECTS	LIMITS OF ACTIVITY	TYPICAL COMPOUNDS	OTHER POSSIBLE COMPOUNDS
Oxidation Inhibitor	Prevent or control formation of varnish, sludge and corrosive compounds. Limit viscosity increase.	Decompose peroxides, inhibit free-radical formation, and passivate metal surfaces.	Can increase oil vapor pressure, promote (in the case of zinc organics) corrosion and cause heavy oil sludging and darkening (in some nitrogen compounds).	Most additives have an optimum temperature range and are not uniformly effective at preventing all forms of catalytic oxidation.	Hindered phenols, bisphenols, metal (especially zinc) dialkyl dithiophosphates, compounds of nitrogen and sulfur.	Barium dialkyl dithiophosphates, phosphites, amines.
Rust Preventive, Liquid Phase	Prevent formation of rust in areas under the oil, especially during equipment shutdown.	Polar type compounds react with or are adsorbed on metal surfaces.	Reduce oil oxidation resistance and promote formation of emulsions.	Only effective in the oil-wetted parts of the system.	Sulfonates, soaps, fatty acids, phosphates, mono- and difunctional organic acids and esters.	Alkyl amines, amine phosphates, acid phosphate esters.
Vapor Phase	Prevent rust formation in areas above the oil level.	Volatile basic compounds are vaporized with water and keep condensate basic.	Reduce oil oxidation resistance and promote formation of emulsions.	Re-inhibition required in systems volatilizing large volumes of water.	Low-molecular-weight amines having a wide boiling range.	
Anti-Foamants	Ensure rapid collapse of large air bubbles; prevent excessive oil oxidation.	Attracted to oil/air interfaces, they lower the surface tension of air bubbles, causing the formation of quick-breaking large bubbles.	Silicone types tend to promote air entrainment (the formation of tiny, long-lasting bubbles). Other types may promote emulsion formation.	Some lubricant additives or contaminants may render anti-foamants ineffective.	Silicone polymers, methacrylate polymers.	Waxes.

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* Derived from Miller [79]

TYPE	REASON FOR USE	HOW THEY WORK	ADVERSE EFFECTS	LIMITS OF ACTIVITY	TYPICAL COMPOUNDS	OTHER POSSIBLE COMPOUNDS
Viscosity Index Improvers	Reduce the rate of viscosity change with temperature.	These polymers are tightly coiled (and relatively insoluble) in oil at low temperatures and uncoiled (and quite soluble) in oil at high temperatures. VI improvers contribute to oil viscosity at higher temperatures preventing "thinning."	Polymers shear in service, thus causing the compounded oil to suffer both "temporary" and "permanent" viscosity loss. When high VI finished oils are desired, the base oils must have low viscosities, hence low flash points.	Many polymers exhibit "VI humps" (e.g., concentration ranges beyond which further additive addition will not increase VI).	Polyisobutylene (such as STP), methacrylate polymers, some copolymers.	Succinimide-acrylic acid reaction products, ethylene-propylene polymer derivatives.
Pour Depressants	Lower the pour point (or "freezing point") of paraffinic oils. Most pourpoint depressions are less than 40°F. (say from 20 to-20°F.) and are achieved with less than 2% additive.	Prevent wax crystal-growth or oil absorption at low temperatures.	None.	The pour-point depression effect of any single polymer is limited and often specific , so combinations of pour depressants are often used.	Methacrylate polymers, alkylated naphthalene or phenols.	Polyacrylamides.

TYPE	REASON FOR USE	HOW THEY WORK	ADVERSE EFFECTS	LIMITS OF ACTIVITY	TYPICAL COMPOUNDS	OTHER POSSIBLE COMPOUNDS
Extreme Pressure (EP), Oiliness & Antiwear.	Modify friction properties, reduce wear, prevent galling and seizing.	Form physical or chemical bonds with rubbing surfaces that provide supplemental "wearing surfaces." The key is friction and wear control, rather than elimination.	Promote oil oxidation, foaming, emulsification and corrosive tendencies. Thermal stability is weakened.	EP agents require heat (generated by metal-to-metal contact) to be effective. Not all desired oiliness properties are contributed by one set of additives. The General Motors Automatic transmission Fluid (ATF) is unsuitable for Ford Transmissions; the Ford ATF does not have suitable friction properties for GM transmissions.	Oilness-fatty acids and soaps. Antiwear-impure tricresyl phosphates, metal dialkyl dithiophosphates. EP-organic phosphates, lead and chlorine compounds.	Organic compounds with barium, antimony, bismuth, silicon, molybdenum, sulfur, phosphorus, nitrogen, halogens, carboxyl or carboxylate salts, silicones, polyphenyls.

TYPE	REASON FOR USE	HOW THEY WORK	ADVERSE EFFECTS	LIMITS OF ACTIVITY	TYPICAL COMPOUNDS	OTHER POSSIBLE COMPOUNDS
Detergents, Dispersants.	Keep sludges suspended and surfaces clean. Dispersion implies only the act of keeping sludges in suspension..	Chemical and physical forces combine to keep sludges solubilized, and thus prevent agglomerating.	Promote emulsification of water. Compete with antifoamants, antiwear, oiliness, EP and antirust additives for interfaces with air and metal.	Eventually, saturation is reached. This is why even 6,000 mi. automotive oils must be changed.	Often dispersants are referred to as "nonmetallic" or "nitrogen containing" organic compounds, while sulfonates, phenates, and other metal or P_2S_5 containing compounds are referred to as "detergents."	Metal containing-barium, calcium, magnesium, zinc organics, succinates, transition metal amino-phosphoro-dithioates, phosphonates, alkyl substituted salicylates; ashless-alkenyl succinimides, alkyl-acylic polymers, succinates, triazine and phosphorus acid, polyhydric alcohols + polycarboxylic acids, modified polyolefins, sulfurization/polyamines, styrene-maleic anhydride copolymers.

TYPE	REASON FOR USE	HOW THEY WORK	ADVERSE EFFECTS	LIMITS OF ACTIVITY	TYPICAL COMPOUNDS	OTHER POSSIBLE COMPOUNDS
Emulsifiers	Hold oil & water together in emulsion-type cutting fluids, coolants and hydraulic fluids.	Polar-type (both ionic or nonionic) compounds line up at oil/water interfaces, and thus they provide solubility bridges between the oil and water.	Reduces oil oxidation resistance. Fights activity of antiwear, EP, oiliness, anti-rust, and anti-foam agents. May cause seal swelling.	Different emulsifiers must be used for every oil, every concentration of water and, often, every service temperature.	Metal sulfonates; glycols; ethoxylated phenols, alcohols or acids; naphthenic acids.	Fatty acid soaps.
Metal Deactivators	Passivate metal surfaces so that they do not act as a catalyst in oil oxidation.	A protective barrier is formed over the entire metal surface.	Often promotes oil color degradation.	Each deactivator must be chosen for the metal it will contact. When competitive surfactants are around, however, effectiveness is limited.	Zinc dialkyl dithio phosphates, metal phenolates, organic nitrogen compounds.	Organic dihydroxy phosphines, phosphites, sulfur compounds.
Other Additives:	Perfumes and formaldehyde compounds as antiodorants with EP additives; alcohols, phenols, chlorine compounds as antiseptics for emulsion lubricants; amine compounds as color stabilizers; polyacrylates and polybutenes as tackiness agents for gear oils.					

APPENDIX C

PITTSBURGH SURVEY METHODOLOGY AND DATA

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METHODOLOGY

SAMPLE DESIGN

In order to define the sample, which would include the entire Pittsburgh Metropolitan area, the six Pittsburgh and suburban telephone directories were used as a source for service station names. These directories were grouped into the following areas: Pittsburgh City, North and West suburbs, Northeast and East suburbs and South and Southwest suburbs. Each area was defined by telephone exchange number and counts were made of the total number for each stratum as shown below:

TELEPHONE AREAS

COMPANY	PITTSBURGH CITY	NORTH AND WEST	NORTHEAST AND EAST	SOUTH AND SOUTHWEST
Amoco	5 of 44			
ARCO	5 of 55		3 of 15	3 of 15
Boron	6 of 66	3 of 16	3 of 17	
EXXON	5 of 44	3 of 22		3 of 14
Gulf	6 of 67		3 of 15	3 of 14
Mobil	3 of 20		3 of 14	
Sunoco	5 of 50	3 of 20		
Texaco	3 of 23			
Other	6 of 142	6 of 90	6 of 75	6 of 63

Where no number appears for a particular company for each stratum, that company was included in the "other" stratum.

Also included in the sample were 4 service stations located on highways and 4 truck stops randomly selected from the entire area.

Service stations were randomly selected within each stratum, making a total of 100 service stations, out of a universe of about 900, to be contacted.

INTERVIEWING EXPERIENCE

Interviewer training was held August 18th for all interviewers working on the study, to insure a thorough knowledge of the study, the questionnaire, and the sample. Interviewers were instructed to approach each assigned service station and ask to speak with the owner or operator. If he was unavailable, appointments were made for a time that was convenient to him. A letter from Response Analysis explaining the nature of the study, that Response Analysis was conducting the Study for the Environmental Protection Agency was handed to the respondent before the interview began. Each respondent was assured through the letter and the interviewer that individual answers would be kept in strict confidence and results would be available only as a statistical compilation. According to the interviewers the majority of respondents were knowledgable and very cooperative.

The importance of each of the one hundred interviews was stressed to the interviewers since no replacements were to be made. Only if the service station was no longer in business, or it had changed companies, was a new station randomly selected to replace it. Every effort was made to complete an interview with each station. The results of the interviewing were as follows:

PITTSBURGH CITY

	#Contacted	Complete	Refused
Amoco	6	4	1
ARCO	5	5	-
Boron	6	6	-
EXXON	6	4	-
Gulf	6	6	-
Mobil	3	3	-
Sunoco	6	4	1
Texaco	3	3	-
Other	8	4*	1

NORTH AND WEST

	#Contacted	Complete	Refused
Amoco			
ARCO			
Boron	3	1	2
EXXON	3	2	1
Gulf			
Mobil			
Sunoco	3	2*	-
Texaco			
Other	8	4*	1

NORTHEAST & EAST

	#Contacted	Complete	Refused
Amoco			
ARCO	3	1	2
Boron	3	2	1
EXXON			
Gulf	3	2	1
Mobil	3	3	-
Sunoco			
Texaco			
Other	6	5	1

SOUTH & SOUTHWEST

	*Contacted	Complete	Refused
Amoco			
ARCO	3	3	-
Boron			
EXXON	4	2	1
Gulf	5	3	-
Mobil			
Sunoco			
Texaco			
Other	9	6	-

* Three questionnaires which were completed,one in each stratum, are not included. These were lost in the mail.

Out of the 4 highway service stations interviewed,3 were completed. Two truck stop interviews were completed of the seven contacted.

The data was collected from 80 service stations,and compiled in order to analyze four areas:

- Oil Changes
- Removal, collection and storage
- Disposal
- Estimates of available wastes

With this information, the availability of wastes and the disposal of them in the Pittsburgh metropolitan area can be determined.

PRIVATELY OWNED VEHICLES

OVERVIEW

Personal interviews with owners or managers of almost 100 service stations, new car dealers, and garages or automobile maintenance facilities were conducted in the Pittsburgh area. There were a number of useful results of those interviews. However, the attempt to gather data to give reasonably precise quantitative estimates of the waste oil collected was unsuccessful. The owners or managers of various facilities for doing oil changes simply did not accurately know how many oil changes they did, nor how much waste oil they collected.

It is our belief, based on the survey experience, that no procedure short of monitoring actual service records for a period of perhaps as long as one year could hope to produce data with any real precision. Aside from such complications as seasonal variations, the basic problem is that there is no reason for the typical maintenance facility to keep records on the number of oil changes, or even on the total amounts of waste oil collected. The result is that the only collectable data involves the perceptions of the facility owner or manager. From the contradictory results obtained by asking each respondent for the same information in different ways, it is clear that these perceptions do not lead to reliable data.

The most important positive result of the survey was to establish that the overwhelming majority of service stations and others who do oil changes on private automobiles do recycle the waste crankcase oil. Almost without exception the maintenance facilities were equipped with underground storage tanks which were emptied relatively regularly by waste oil collectors. Generally speaking, the collector provides the convenience of a collection service in return for the oil. It is partly for this reason that the service station owners generally did not even know the total amount collected.

OIL PER SERVICE STATION

The great bulk of the survey interviews were with service station owners and/or managers. A total of 83 interviews were actually carried out, although three of these were lost in the mail when returned from the interviewer. Thus, the tabular results at the end of this Appendix are actually based on 80 interviews.

Each respondent was asked in a number of different ways about his oil usage and waste oil collection. The intent of these multiple approaches to obtain the same data was as a check on intentional misrepresentation. The results, however, appear to show unintentional, uninformed error rather than misrepresentation. This follows from the fact that the actual results of the various approaches for each respondent are, if anything, almost random in their variations.

The following tables give the results of three ways of asking respondent service station owners or managers for the amount of waste oil they generate per year. In the first table, two columns of figures on waste oil are shown. The first is based on, to us, inexplicable testimony as to quarts of oil removed from a car per oil change. The second gives the waste oil removed from crankcases assuming an average of 4.5 quarts (1.13 gallons) per change.

This inability to accurately estimate the waste oil they remove from crankcases turns out to have occurred in, at least, one and quite probably other previous studies. For example, a study in Maryland,[5] the report of which became available after this study was carried out, shows the same phenomena. Again the number of oil changes indicates far less waste oil available then does the claimed oil collectable.

Using even our estimate of 4.5 quarts per oil change (Table C-1, last column), the three results obtained in the survey vary by a factor of almost two to one. Clearly the precision of any results, obtained from data with such variability, is sharply limited. The best we are able to do is to make some judgmental decision. For the remainder of this report we propose to simply roughly average the three results (allowing for non-response) and use a figure of 1,100 gallons per station per year. This corresponds to about 20 oil changes per station per week. While this figure is obviously just a ball-park estimate which must be checked against other approaches, it does have at least the minimal virtue of seeming reasonable from subjective experience.

TABLE C-1 OIL CHANGES DONE, ALL VEHICLES* GALLONS/YEAR

		SERVICE STATIONS	TESTIMONY TOTAL REMOVED FROM OIL CHANGES	APPROXIMATE TOTAL OIL REMOVED ON BASIS OF 4.5 QUARTS PER CHANGE
No Oil Changes		3	--	---
Average Number of Changes Per Week	1-5	13	1,750	2,200
	6-10	20	6,180	10,100
	11-15	20	11,620	16,200
	16-20	9	6,470	10,100
	21-25	7	7,400	9,600
	26 or more	6	11,980	15,200
	Don't Know	2	--	---
TOTAL GIVEN VALUE		78	45,400	63,400

* Based on Questions 5,11,14,18

TABLE C-2. OIL BOUGHT AND USED FOR OIL CHANGES*

	Gallons Per Year	%
SOLD AT ISLAND	46,983	39.9
USED FOR OIL CHANGES	70,419	59.8
OTHER (SOLD TO INDIVIDUALS FOR BOATS, LAWN MOWERS)	452	0.4
TOTAL OIL BOUGHT	117,854	100.0

* Based on Questions 1,4

TABLE C-3. WASTE AVAILABLE AND COLLECTED IN GALLONS PER YEAR*

	TOTAL WASTE AVAILABLE	TOTAL STORED FOR COLLECTION	TOTAL UNCOLLECTED
WASTE OIL	112,780	111,400(99%)	1,370(1%)
OIL FROM INDIVIDUALS	280	280(100%)	---
SOLVENTS	155	35(23%)	120(77%)
GREASES	14	13(93%)	1(7%)
TRANSMISSION FLUID	437	327(69%)	146(31%)
BRAKE FLUID	34	29(85%)	5(15%)
ANTIFREEZE	4,808	58(1%)	4,750(99%)
TOTAL	118,508	112,142	6,392

* Based primarily on Question 34

AUTOMOBILE DEALERS AND AUTOMOTIVE SERVICE CENTERS

The data on automobile dealers and other forms of automotive service centers, such as retailers, are based on 10 interviews in the Pittsburgh area. From these interviews we estimate that the typical service center might do about 40 oil changes a week and the typical new car dealer might do about 80.

OVERALL PRIVATE VEHICLE WASTE OIL

There are two ways of estimating the total number of service stations in the Pittsburgh metropolitan area. The first is by a direct count of service stations which are listed in the Yellow Pages used in drawing the sample. These Yellow Pages cover about 80% of the population in the Pittsburgh metropolitan area, although a substantially smaller fraction of the land area. The actual count of service stations was approximately 1,000. If one assumes that the oil changes done are proportional to population, then the equivalent number of service stations doing an average of 20 oil changes per month each would be approximately 1,250. Due to the greater physical area on the communities not covered by those Yellow Pages used in the survey, the number of service stations might be larger, but the number of oil changes per station in the less densely populated areas would presumably be smaller.

One alternative method for estimating the number of service stations is use of the 1967 Census of Businesses. According to the Census Bureau there were 2,069 service stations at that time in the four-county Pittsburgh SMSA. However, we believe this figure to be high in relation to our results, because of two reasons: first, the aforementioned question of stations in low density areas; second, the counting by the Census Bureau of garages or service centers such as those at many Sears stores, which we classified in other categories.

Allowing for limited non-listing in the Yellow Pages, we take as a best estimate 1,400 equivalent service stations (i.e., service stations with maintenance equivalent to those which formed the population for sampling).

For new car dealers and others we made direct counts of the firms listed in any one Yellow Page Directory. This is reasonable, because virtually all firms of this type turned out to be listed in each area Yellow Pages, with the listings for any particular make of car being separated by town. Using this approach we get about 130-140 new car dealers and 60-70 service centers or equivalent maintenance facilities. Using these admittedly rough and imprecise figures as a basis, the overall total private vehicle waste crankcase oil available for recovery per year appears to be approximately:

$$1{,}400 \text{ service stations} \times \frac{1{,}100 \text{ gallons}}{\text{Service station}} = 1.5 \text{ million gallons}$$

$$+\ 135 \text{ new car dealers} \times \frac{4{,}400 \text{ gallons}}{\text{Dealer}} = 0.61 \text{ million gallons}$$

$$+\ 65 \text{ maintenance centers} \times \frac{2{,}200 \text{ gallons}}{\text{Center}} = 0.15 \text{ million gallons}$$

$$\text{Total} = 2.3 \text{ million gallons per year}$$

ANOTHER APPROACH AND PRECISION

Another way to approach the quantity of waste oil recoverable from private automobiles is:

From national figures on cars per person, estimate the number of private automobiles in Pittsburgh: 900,000;

Estimate the number of oil changes per car per year subjectively at 3.7 (allowing for 10% of cars not using service stations and 3 changes);

Estimate the quantity of oil recoverable at 4.5 quarts or 1.13 gallons;

giving an estimate of 2.6 million gallons of service station recoverable waste oil. WE EMPHASIZE that we do not have any data on which to base the number of service station changes per car and only data which we have chosen earlier to disbelieve on quarts per oil change. Nonetheless, in light of the pilot nature of the study and the results and claims of previous studies it seems worthwhile to estimate the kinds of numbers obtainable in various ways.

These numbers give some idea of the precision in the survey based figure of 2.3 million gallons given above. We believe that an allowance for error of as much as ± 33% must be attached to these figures.

ORGANIZATIONALLY OWNED VEHICLES

INTRODUCTION

This section deals with vehicles of all types owned by organizations of all types. The data is drawn from about a dozen interviews with a wide variety of types of organizations in the Pittsburgh area, and from various published industry sources. No serious attempt is made to give precise quantitative results, although some effort is made to set order of magnitude estimates of the quantities of recoverable waste oil generated. Most of this waste oil is available for recycling although a substantial and growing fraction may not be. The oil which is not or will not be available for recycling is primarily from "company" cars of a wide variety of organizations ranging from utilities and government to manufacturing and distribution firms. The main intent is thus to provide a catalog of uses indicating at least an estimate of the order or magnitude of each use.

There are five main categories of vehicles considered:

Rental fleets: cars or trucks available for rental by the general public, where the renter provides the driver.

For-hire-trucking: trucks available for freight delivery of one form or another, but where the trucking firm provides the driver. This category includes trucks involved in distribution functions such as United Parcel and the U. S. mail.

Direct organizational use: cars and trucks used directly by organizations as an integral part of their own business.

Automotive forms of public transportation: basically buses and taxis.

Non-automotive forms of transportation: various forms, such as planes, ships and trains.

RENTAL TO THE PUBLIC

From the viewpoint of this study there are, at least, four different types of rental car and truck organizations dealing with the public.

Major rental firms with their own service facilities.

> Basically, these are the three largest national firms (Hertz, National and Avis) and such other local or regional firms as happen to have a substantial concentration of cars in a single place and do their own servicing. Note that this category includes only situations where the present company does the servicing, not the franchise owner.

Rental firms using others for the servicing, where there are generally service stations.

> Included here are such firms as Budget and Econo-car, as well as local firms.

Service stations which have rental facilities.

> Many of these have franchises from a national firm, but are included when they are responsible for their own maintenance.

Auto dealers who also rent cars.

> These firms generally use their own new car service facilities for servicing their own rental cars.

As considered here, rental includes both short and long term arrangements, but only where the dealer, and not the customer, is responsible for maintenance. Trucks, small car trailers, and similar vehicles account for a substantial portion of the total rental vehicles. For instance, various industry reports indicate that nationwide Hertz, Avis and National together own about 300,000 cars and about 50,000 trucks.

Altogether, rental vehicles probably make up no more than about one percent of cars, and a slightly higher proportion of trucks. However, rental cars generate a significantly higher proportion of crankcase waste oil available for recycling, since they get so much greater usage per car. Typically, a rental car might be driven about 40,000 miles, or 2 1/2 to 3 times as many miles as a private automobile, with a correspondingly higher oil usage (40,000 miles in one year that is). Further, being new cars they would not usually do oil changes by replacement of burnt oil, as sales of oil at the island indicate is the case in many older cars.

The data gathered in Pittsburgh on this class of users was useful mainly in indicating the range and variety of rental car firms. Four interviews were conducted, with three of the respondents also involved in selling and servicing cars other than their own rental cars.

We estimate that the approximately 150 rental agencies listed in the Pittsburgh telephone book Yellow Pages might do as many as 1,000 oil changes per week, and generate in the order of 60,000 gallons of waste oil per year.

This is slightly over two percent of the oil available from privately owned autos. In dealing with rental firms in a national study, care will have to be taken to distinguish between facilities used for rental cars only, and facilities also used for other purposes. The purpose would be not only to be sure of getting a representative sample, but also to avoid the possible double counting implicit in separate samples of rental firms, new car dealers, etc.

FOR-HIRE-TRUCKING

According to the Fausett study,[80] for-hire-trucking accounts for about seven percent of the waste oil generated by transportation modes. While some trucking firms have their own facilities for maintenance, others and particularly individual owners or small delivery services use public garages or service stations. These latter were covered in the previous section.

No interviews were done in the Pittsburgh study with trucking firms which do their own servicing, mostly because it was felt that they would add little or nothing to our qualitative understanding of the problems. Large trucking firms are presumed to behave like other fleet owners, with whom a number of interviews were completed. Those interviews are discussed below.

In any national oil recycling study, two classes of for-hire trucks would have to be considered; inter-city and intra-city. Inter-city trucking would include state and federally licensed trucking firms, licensed for over-road freight. A special category of such firms are movers licensed to move furniture or other office or household goods. Intra-city trucking includes distribution firms such as United Parcel, individual department stores and the great majority of the United States Postal Service vehicles.

NOT-FOR-HIRE ORGANIZATIONAL CARS AND TRUCKS

Cars and trucks used by organizations for their own purposes, i.e., not for delivery, whether of cargo, packages or mail, are considered in this section, but only when the fleet is serviced by the owning organization. Three main types of organizations appear to maintain fleets of sufficient size to be of interest.

> Utilities: Interviews with two utilities indicated that both have substantial fleets, with each vehicle being used in an extensive fashion. Their vehicles fall into three classes: "company cars," i.e., cars used for internal company business; cars and light trucks (often quite large) used for general system development and maintenance. While the nature of these vehicles is quite different, all of them are typically serviced in one (or more than one) common maintenance area. The estimated total number of such utility vehicles is about 2,000 vehicles in the Pittsburgh area, or about one vehicle per 1,000 population. Projected nationwide this would be equivalent to about 200,000 to 300,000 vehicles which combined (due to intensive use) might generate between one and two percent of available waste crankcase oil.
>
> Manufacturing and merchandising firms: Many large companies have extensive vehicular fleets within plants (e.g. lift trucks), for between-plant movement of materials, and for general company purposes. The main difference between these firms and utilities is concentration. A large industrial firm may have 20 to 50 plants (or more) scattered across the country, with concomitant problems in collecting the oil and on gathering data on procedures followed. We spoke with three major Pittsburgh manufacturing firms.

Governments: Governments employ a wide range of vehicles. Two features of virtually all governments are fleets of vehicles used by police and fire departments. In addition, many larger governments have fleets for various other uses, such as what amount to company cars, sanitation vehicles and, in some cases, public transport (to be discussed below). Generally, governments with a fleet of any substantial size appear to do their own servicing. Based on a Pittsburgh interview plus experience with a number of local governments in other areas, governments' own facilities may not always be as sophisticated or as conscientious in recycling waste oil as are utilities or large corporations. Specifically, governments may tend to use waste oil for their road departments for dust settling. They are, however, a fairly easy group to survey and then incorporate into a waste oil recycling network.

BUSES AND TAXIS

Our interviews in Pittsburgh indicated that taxi fleets of sufficient size who have their own garages do appear to presently recycle oil in the same way as any other garage or service station; that is, by pickup by a waste oil collector. The quantities involved would appear to be substantial, given the high number of low speed (i.e., high heat) miles driven by the average taxi. Figures in the neighborhood of about 10 gallons per cab per year seem consistent, both with the limited Pittsburgh data, and known taxi usage. If so, and assuming one fleet-serviced taxi per 1,000 people, fleet taxis in the Pittsburgh area would generate about 20,000 gallons of waste oil per year, or less than one percent of that generated by privately owned vehicles.

Buses fall basically into two categories: private and public ownership. Neither category presents any unusual problem with the possible exception of long-haul buses which are similar to larger trucking firms in their diffusion.

NON-AUTOMOTIVE VEHICLES

The Fausett study[80] indicated that airplanes generate less than one percent of all available oil generated in transportation. Three interviews at the Pittsburgh Airport with the airport director, an airline, and the major gasoline firm based at the airport, tended to confirm this low figure. On the other hand, the facilities they do have for reclaiming engine oil are relatively sophisticated.

While a national study would certainly have to deal with railroad and ship uses, no attempt was made to do so in the Pittsburgh study. Railroads in particular generate large quantities of oil, according to the Fausett study. However, this is concentrated in a relatively few maintenance yards, and so appears fairly easy to survey. Ships, on the other hand, present a number of problems from diffusion of ownership to spillage at sea. Thus care would have to be taken in a national study to include this segment accurately.

TOTAL VEHICULAR CRANKCASE OIL - TWO APPROACHES

Based on the relatively meagre results of this study, on the Fausett study,[80] and on aggregate data on total vehicles, we estimate that in Pittsburgh organizationally owned vehicles have somewhat over one-half the available oil of privately owned vehicles. Using the rough service station survey results of the previous section this would indicate that organizationally owned vehicles generate between 1.1 and 1.6 million gallons of recoverable crankcase oil per year.

Altogether, then, we estimate vehicular crankcase oil at about 2.7 to 4.8 million gallons per year with a best survey estimate of 3.7 million gallons. To give some idea of the relationship of these numbers to the number of vehicles in the Pittsburgh area, we consider the following:

> Altogether there are approximately 1.4 million automotive vehicles in Pittsburgh. If each vehicle produced about 3 gallons of recoverable waste oil per year (i.e., a little under 3 oil changes per year), the total amount recoverable would be about 4.2 million gallons. This would be in the upper range of the survey indicated data, and quite possibly indicates the survey figure is somewhat low.

NON-VEHICULAR USES

INTRODUCTION

This section deals with non-vehicular usage. No attempt is made here to be complete. However, five major classes of generation of waste oil are identified. These are lubrication (including cutting and other moving parts usage), electrical insulation, solvents, processes, and spillage (including pipeline spillage during transportation of the oil itself). A striking (if only tentative) result using our somewhat limited data is that lubrication uses may rank as low as fourth among the five classes considered in terms of quantity of waste oil recoverable or available for recycling. Specifically, use of oil for electrical insulation, for solvents, and the amount of lost oil (spillage during transportation of the oil) all seem to produce greater quantities of oil suitable for recycling. We emphasize that the accuracy of this conclusion requires substantial further testing, with the surest approach being a projectable national survey. On the other hand, the conclusion is consistent with a reasonable interpretation of previous work. For instance, in the Maryland study,[5] two-thirds of all non-vehicular industrial oil had to be classified "other" and less than one-fourth was grouped in the three separate lubrication categories specified.

LUBRICATION

It appears that lubrication of machines today is done with very limited amounts of recoverable oil. Our first indication of this phenomenon was in the pretest stage. We could not find machine shops in New Jersey which generated sufficient waste oil to justify an interview. Other studies, notably the Maryland one, have also found lubrication to account for only a small fraction of oil used.

Interviews with major Pittsburgh firms (including the utilities), bore out this initial impression, with one exception. Rolling mills do generate substantial amounts of lubrication waste oil. This oil is used over and over but eventually becomes contaminated. The firm we spoke with, which generated substantial rolling mill waste oil, was already using it for fuel.

The utilities we talked to had little if any lubrication oil available. From our New Jersey experience the same would apply to smaller machine shops in general. On this basis we would anticipate that a national study should expect most lubricating uses to be in heavy industrial settings such as rolling.

NON-LUBRICATION INDUSTRIAL USES

A major use of oil for industri purposes is in the insulation of a vast array of electrical equipment, including cable, switches and generators. The waste oil develops from spillage, contamination, and obsolescence of the particular equipment. Waste oil of this type was the single largest kind found in interviews with utilities and in manufacturers of electrical equipment.

Lube type oils are used as a solvent or process oil in a wide variety of industrial processes. Any resulting wastes can be segregated into two classes: those uses where the oil is reclaimable in an economic manner either because it has not been appreciably altered in use or because the material dissolved in it can be easily removed, and those uses where the dissolved material can only be removed at considerable cost. In interviews with industrial users we found a significant amount of reclaimable oil. However, our data is far too sparse to allow meaningful statements about total oil available for recycling.

SPILLAGE

In interviews with collectors, we found that one of the largest, if not the largest single source of waste oil in the tri-state area centered around Pittsburgh, was spillage of the oil in the process of transportation, specifically at pipeline pumping stations. Given the very large quantities of oil that may be involved, spillage of even a small fraction means the availability of large quantities of oil. The characteristics of this oil may vary from day to day, and this oil actually includes such types as home heating oil.

OVERALL AVAILABILITY

Industrial uses of oil are believed to account for about 55-60% of all oil sold in the U. S. However, they account for a far smaller portion of recoverable oil (probably no more than one-quarter) and a still smaller fraction of oil available for external recycling. We would very roughly estimate that industrial oil accounts for around 20% of the used (as opposed to pipeline spilled) oil presently being collected in Pittsburgh. This estimate is based primarily on subtracting vehicular estimates from the total collection figures to be presented in the next section. Further, waste oil available for external recycling from industrial uses is surely declining as industry more and more uses any large quantities for its own fuel needs.

COLLECTOR SURVEY AND PRELIMINARY MATERIAL BALANCE

COLLECTORS-ANOTHER APPROACH TO AVAILABILITY

In the previous sections we have dealt with qualitative and quantitative data related to the generation of waste oil. It is also possible to approach waste oil recycling from the other end, that is from the viewpoint of what is presently collected. This viewpoint has the obvious limitation that it can describe only that oil which is already being handled in at least potentially environmentally sound ways. Given the very wide gaps and imprecisions in our knowledge of the quantities of waste oil generated, it cannot even by subtraction indicate the quantities either being used or internally recycled by the generators themselves or disposed of by dumping.

Once these limitations are understood it is useful to develop an understanding of what is presently being recovered. We conducted six interviews with collectors of waste oil in the Pittsburgh area. Of these, three turned out to be middlemen who merely collect the oil for delivery to the storage and refining plant of the one large operation. We estimate on the basis of these interviews that the total waste or spilled oil collected by recyclers located in the Pittsburgh area to be about 11 million gallons per year. This, however, includes significant quantities of oil actually generated outside the Pittsburgh SMSA, including West Virginia, Maryland and Ohio.

On the other hand, almost without exception, every Pittsburgh area generator of waste oil, and in particular the service stations who could name their collector, specified a Pittsburgh based firm. Thus, there was a significant net inflow of waste oil for recycling into Pittsburgh. Overall, based on interviews, we estimate that the Pittsburgh based collectors gather

> about 4.5 to 5.5 million gallons from the Pittsburgh area;
>
> about 3.0 to 3.5 million gallons of pipeline oil spillage from a wide area around Pittsburgh; and
>
> about 3.0 to 3.5 million gallons from other than pipeline sources outside Pittsburgh.

PRELIMINARY MATERIAL BALANCES

Given the vastly different distribution, usage, waste generation and collection procedures, it is worthwhile to divide an oil material balance into two segments; automotive and industrial. In this section we describe some of the factors involved in such balances and give some very tentative figures for Pittsburgh.

Automobile oil: Total automobile oil sold in the United States is estimated at about 1.1 billion gallons annually. Figures on a state by state basis show that sales are far from uniform. Specifically, states with the majority of their populations in metropolitan areas have consistently lower per capita usage than do farm states or states with widely scattered populations. Elsewhere in this report we estimate that just about half of all oil sold is available for recycling. Two major factors in this lower than usual estimate are the large amounts of oil burnt in 2 cycle engines and the amounts of industrial auto fleet oil which is used internally. This would imply that in Pittsburgh a total of perhaps 7 million gallons of new oil was sold per year with about 4 million gallons being available for recycling. Extrapolating from the national sales figures and taking into account the lower per capita usage in metropolitan areas, these figures still seem low. A more reasonable figure appears to be about 9 million gallons sold implying about 5 million gallons available for recycling. It is, of course, feasible that a significant portion of the difference between 4 million and 5 million gallons is being recycled by fleet auto owners themselves.

Industrial users: Based on survey both from collectors and large industrial users, the quantities of industrial waste oil collected by outside firms is relatively small and declining. An overall figure for Pittsburgh of approximately one million gallons is probably about the right size. This compares with projected Pittsburgh area sales of perhaps 15 million gallons. Of the remainder, substantial amounts are actually recoverable, but are not available for external recycling because of internal recycling or use.

Combined: Overall, with the usual cautions on gross margins or error, we estimate, based on all the various approaches considered, that the individuals and firms in Pittsburgh

1. Purchase about 24 million gallons of oil per year (9 million gallons automotive and 15 million gallons industrial).
2. Use up directly or in secondary uses about 19 million gallons per year.
3. Have available for external recycling, almost all of which is actually being recycled, about 5 million gallons per year.

TIME STARTED ________________

OIL RECYCLING

My name is ________ and I am an interviewer for Response Analysis Corporation of Princeton, New Jersey. We are working on a study about the use of oil in service stations. About two billion gallons of oils and lubricants are used in service stations each year. Given the energy problem in the United States today, it is important to find out in as much detail as possible the use of all petroleum products.

The Environmental Protection Agency of the United States Government is sponsoring an area-wide study in the Pittsburg area. Please be assured, however, that your name and individual answers will be kept in strictest confidence by Response Analysis, and that only statistical compilations will be made available to the sponsors of this study.

1. To begin with, we would like to get some idea of the amount of oil that you buy...

   a. How many gallons of oil can you store in your station? ________________

   b. And how many gallons of oil do you order each time you get a delivery? } Total 119,178 gal/yr

   c. And how often is oil delivered to you? ________________

2. When you buy oil, is it always in quart cans or do you buy some in gallons or in other ways?
   201 QUARTS (GO TO Q.4)
   2 GALLONS
   3 OTHER -- SPECIFY:
   43 Both
   6 Other
   11 O.K.

3. Over the last year, what percent of the total volume of oil you have bought has been in cans, other than quart cans? 27% PERCENT

4. Next, I would like to discuss some of the ways you sell oil...

   a. First, what percent of the oil you sell is added on right at the island? That is, to make up for oil that is burnt off? 46,983 gal/yr.

   b. And what percentage is used by you for oil changes? Total 70,419 gal/yr

   c. Are there any other ways in which you sell oil? For instance, in bulk or in small amounts for use outside the station?
   131 YES
   57 2 NO (GO TO Q.5)

   d. Could you tell me about them, please? 452 gal/yr
   ____

5. About how many oil changes on cars and other vehicles (such as a snowmobile) do you do at this station?

   INTERVIEWER NOTE: IF RESPONDENT DOESN'T KNOW, PROBE. IF RESPONDENT GIVES A NUMBER, SUCH AS 2 OR 3, ASK IS THAT PER DAY, ETC. PLEASE BE SURE TO NOTE BOTH THE NUMBER AND THE TIME PERIOD. IF ZERO, GO TO Q.13.

6. Do you use a rolling storage tank when doing an oil change?

   52 1 YES
   25 2 NO (GO TO Q.10)

7. What is the capacity of the rolling storage tank in gallons?

   0-5 GALLONS 15
   6-15 GALLONS 12
   16+ GALLONS 25

8. How often do you empty the tank?

   1 EVERY OIL CHANGE
   10 2 EVERYDAY
   22 3 WHENEVER IT IS FULL
   20 4 OTHER -- SPECIFY:
   ALL AT FIXED INTERVALS

9. About how many gallons of oil do you empty from the tank each time?

10. When you change oil, how often do you change the oil filter?

    34 1 EVERY TIME
    19 2 EVERY OTHER TIME
    24 3 OTHER -- SPECIFY:

11. Aside from the oil filter, what do you estimate is the average number of quarts of oil you put into a car during an oil change?

    AVERAGE JUST OVER 4

12. Again, aside from the oil filter, what do you estimate is the average number of quarts of oil you take out of a car during an oil change?

    Total Car + truck
    45,397 gal/yr.

13. Do you ever change oil on trucks?

    38 1 YES
    42 2 NO (GO TO Q.19)

14. About how many truck oil changes do you do per week?

    NONE DO MORE THAN 6 PER WEEK - MOST DO 1-3

15. Do you always change the truck's oil filter?

    25 1 YES (GO TO Q.19)
    13 2 NO

16. About what percentage of the time do you change the oil filter on a truck?

17. Aside from the oil in the filter, what would you estimate is the average number of quarts of oil you put into a truck during an oil change? ______

18. Aside from the oil in the filter, what would you estimate is the average number of quarts of oil you take out of a truck during an oil change? ______

19. Do you ever take waste oil from individuals, for instance, oil they have drained from a car or snowmobile themselves?

5 1 YES
75 2 NO (GO TO Q.22)

20. About how much waste oil do you take from individuals (in gallons) per month?

Total
276 gal/yr

21. Now I'd like to talk for awhile about some other products, such as diesel oil, greases, solvents and transmission fluids. . .

First, about how much do you buy a year wholesale of each of the following:

a. Solvents 4659 gal/yr.
b. Greases 3036 gal/yr
c. Transmission fluids 7443 gal/yr
d. Brake fluids 1702 gal/yr.
e. Diesel oil 0
f. Antifreeze 16507 gal./yr

Is there anything else of a similar type that you buy in quantities of fifty gallons or more per year? Please describe them, and the amounts purchased of each one:

1,110 gal/yr.

22. On the other hand, how many gallons of each of these same products would you estimate that you remove from cars each month?

a. Solvents 120 gal/yr

b. Greases 14

c. Transmission fluids 446

d. Brake fluids 34

e. Diesel oil 0

f. Antifreeze 4828

g. Others (mentioned in 21) 0

23. Do you have any agreements with any industrial plants or others to store wastes they may develop?

0 1 YES
2 NO (GO TO Q.25)

24. Could you tell me about them, especially the quantities involved?

25. What storage facilities do you have for waste oil?

70 { 1 UNDERGROUND TANK
2 ABOVEGROUND TANK }
3 3 NONE (GO TO Q.45)
4 4 OTHER -- SPECIFY:

26. How many gallons is the capacity of the tank?

200-300 GALLONS 7
500-550 GALLONS 34
800-1000 GALLONS 19 OTHERS- 19

27. Of what material is it made?

1 IRON OR STEEL
2 2 OTHER METAL
2 3 FIBERGLASS
4 OTHER -- SPECIFY:

28. Do you happen to know how old the tank is?

36 IN RANGE 5-15 YEARS 25 DON'T KNOW
OTHERS SCATTERED

29. Do you have any special storage facilities for waste products other than oil?

3 1 YES
77 2 NO (GO TO Q.31)

30. Could you describe them please?

31. a. What do you do with waste solvents and greases?

29 1 SAME STORAGE TANK AS OIL 48 gal/yr. collected
2 STORAGE FACILITIES DESCRIBED IN Q.30 ABOVE
12 3 NOT ENOUGH TO MATTER
4 4 SOAK INTO RAGS, ETC. FOR DISPOSAL
4 5 DUMP ON GROUND OR IN SEWER
2 6 OTHER -- SPECIFY: ____________________

120gal. yr. uncollected

b. What do you do with waste transmission and brake fluid?

54 1 SAME STORAGE TANK AS OIL 356 gal./yr. collected
2 STORAGE FACILITIES DESCRIBED IN Q.30 ABOVE
5 3 NOT ENOUGH TO MATTER
4 SOAK INTO RAGS, ETC. FOR DISPOSAL
6 5 DUMP ON GROUND OR IN SEWER
6 OTHER -- SPECIFY: ____________________

151 gal/yr. uncollected

c. How about waste diesel oil?

4 1 SAME STORAGE TANK AS OIL
2 STORAGE FACILITIES DESCRIBED IN Q.30 ABOVE
16 3 NOT ENOUGH TO MATTER
4 SOAK INTO RAGS, ETC. FOR DISPOSAL
5 DUMP ON GROUND OR IN SEWER
6 OTHER -- SPECIFY: ____________________

d. And finally, how about used antifreeze?

3 1 SAME STORAGE TANK AS OIL 58 gal/yr. collected
2 STORAGE FACILITIES DESCRIBED IN Q.30 ABOVE
4 3 NOT ENOUGH TO MATTER
4 SOAK INTO RAGS, ETC. FOR DISPOSAL
64 5 DUMP ON GROUND OR IN SEWER
6 OTHER -- SPECIFY: ____________________

4750 gal/yr. uncollected

32. To change the subject slightly, about how often do you clean your gasoline tanks? (PROBE: IF RESPONDENT SAYS SOMETHING LIKE WHENEVER THEY NEED IT ASK, Well about how often is that?)

1 WEEKLY
3 2 MONTHLY
2 3 TWICE A YEAR
4 YEARLY
6 5 OTHER -- SPECIFY: ____________________
61 6 NEVER (GO TO Q.34)

33. Could you tell me how you do it and what you do with the residue?

34. Altogether, about how many gallons of wastes, including oil, would you estimate that you have a month? Waste per year 110,605 gallons

35. Do you have some regular provision for picking up the wastes you store? For instance, someone who comes around regularly with a tank truck?

6 D.K
1 YES
2 NO (GO TO Q.45)

36. What is the method?

72 1 TRUCK
2 OTHER -- PROBE TO GET AS COMPLETE INFORMATION AS POSSIBLE, THEN SKIP TO Q.46
2 D K.

37. How often does the truck come around? 75% ON REGULAR BASIS
25% ON CALL

38. Do you happen to know the name and address of the firm which does the pick up? If so, what is it?

NAME ____________________

ADDRESS ____________________

____

39. a. Do they charge you for pick up, or do you get paid or is it simply free pick up?

21 1 CHARGED
3 2 PAID
45 3 FREE (GO TO Q.40)

b. How much per gallon are you (charged/paid)? LOAD CHARGES ABOUT $10-15/LOAD
GALLON CHARGES $.01 TO .05/GALLON

c. About how much were you (charged/paid) the last time your waste oil was picked up? ____________

(INTERVIEWER: ENCOURAGE RESPONDENT TO CHECK FIGURES IF HE INDICATES HE WOULD LIKE TO)

GO TO Q.41.

40. About how many gallons do they pick up each time? Waste picked up per year - 75 190

41. Do you make provision for the pick up yourself, or does ____________ (NAME OF OIL COMPANY) do it for you?

51 1 SELF 27 DK
8 2 OIL COMPANY ______
12 Collector Initiated

42. How interested does ____________ (NAME OF OIL COMPANY) seem to be in this problem? Would you say they are

10 1 very interested
12 2 somewhat interested
3 3 a little interested
41 4 not interested

43. Has there been any change in their interest in the past year?

4 1 YES
65 2 NO (GO TO Q.46)
4 DK

44. In what way has there been a change? Please describe this change for me.

GO TO Q.46.

45. How do you dispose of your waste oil? (INTERVIEWER: IF RESPONDENT IS HESITANT OR NERVOUS, REMIND HIM THAT THE INTERVIEW IS CONFIDENTIAL.)

46. Have there been any changes in your disposal procedures in the past year, including any changes in the cost to you?

6 1 YES
73 2 NO (GO TO Q.48)
1 D.K.

47. Could you describe these changes to me, please?

48. Finally, I would like to ask you just a few background questions.

Is this station privately owned, or owned by ________________?

30 1 PRIVATE
50 2 OIL COMPANY ______________________________
(NAME OF OIL COMPANY)

49. And about how many hours a week are you open?

50. And about how many gallons of gas do you pump a week?

UNDER 7,500	32
7,500 - 10,000	17
OVER 10,000	19
REFUSED, DON'T KNOW	12

INTERVIEWER, COMPLETE THE FOLLOWING INFORMATION AFTER LEAVING THE PREMISES.

51. TIME INTERVIEW ENDED ______________________

52. LENGTH OF INTERVIEW IN MINUTES ______________

53. RESPONDENT WAS
38 1 VERY KNOWLEDGABLE
35 2 SOMEWHAT KNOWLEDGABLE
2 3 NOT KNOWLEDGABLE
5 DK

54. RESPONDENT WAS
58 1 VERY COOPERATIVE
11 2 SOMEWHAT COOPERATIVE
3 3 NOT COOPERATIVE
2 4 ANTAGONISTIC
6 DK

54. APPEARANCE OF SERVICE STATION

24 CLEAN SERVICE BAYS
37 ONLY SMALL OIL SPOTS AND WASTE IN BAYS
11 CONSIDERABLE OIL SPOTS AND WASTE IN BAYS
2 FILTHY SERVICE AREA, LARGE AMOUNTS OF WASTE OIL AND OTHER WASTE PRODUCTS

55. ANY APPEARANCE THAT OIL AND PETROLEUM WASTE PRODUCTS ARE DISPOSED OF ON THE PREMISE OF THE STATION OR ADJACENT TO IT?

12 YES (EXPLAIN AND DESCRIBE EVIDENCE)
4 POSSIBLY
64 NO

56. LOCATION OF SERVICE STATION

3 INNER-CITY, URBAN
11 CITY, BUSINESS DISTRICT
3 CITY, INDUSTRIAL AREA
16 SUBURBAN, RESIDENTIAL AREA
35 SUBURBAN, BUSINESS/INDUSTRIAL AREA
6 SMALL TOWN OR VILLAGE
2 RURAL-URBAN FRINGE

57. 18 VERY BUSY INTERSECTION
8 INTERSECTION
43 ON A BUSY STREET
6 ON A QUIET STREET
4 ADJACENT TO TURNPIKE OR INTERSTATE HIGHWAY

58. STATION IS ADJACENT TO OR NEAR
1 EMPTY LOTS
2 STREAM OR CREEK

APPENDIX D

SURVEY OF WASTE OIL COLLECTION AND PROCESSING

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WASTE OIL COLLECTORS

- Types and sizes of businesses
- Sources of waste oil
- How collected oil is disposed of

WASTE OIL COLLECTORS

THIS STUDY ENCOMPASSES BOTH WASTE OIL COLLECTORS AND COLLECTOR/PROCESSORS.

-- Collector/processors constitute more than one-third (39%) of firms involved in collecting, storing and processing waste oil (Table 1).

Later on we learn those firms involved in processing feel their business is increasing, while those only collecting feel that their business is either declining or just not expanding.

-- Most collectors who do not also process their own waste oil have no storage facilities of their own. They commonly fill trucks to capacity and then transport the waste oil directly to a processor or user.

TABLE D-1

Types of Waste Oil Collectors

Q. 6: Do you have your own storage facilities for the oil you collect, or do you only transport the oil to another waste oil collector or processor?

Q. 9c: What do you do with the waste oil when you remove it from storage. Do you take it to another collector or processor?

Q. 9e: What do you do with the waste oil when you remove it from storage. Do you take it to your own processing or rerefining plant?

	Total = 100
Collectors	
Take waste oil to others for storage	36
Have own storage facilities, but no processing facilities	25
Collector/Processors	
Both collect and process waste oil	39*

---

*Although eight of the 39 collector/processors do not have any collection capacity of their own, they do have a working relationship with collectors.

SOURCES AND AMOUNTS OF WASTE OIL COLLECTED DIFFER GREATLY BETWEEN COLLECTORS AND COLLECTOR/PROCESSORS.

-- While service stations/car dealers and industries are collectors' most common sources of oil, car and truck fleets, marine sources and railroads are also significant. Nearly 60% of all oil they collect comes from one source -- stations and dealers, as shown in Table 2.

-- Five types of waste oil sources are found among 40% or more of collector/ processors, while only three of these are sources for 40% or more of the collectors.

-- One point of contrast involves collector-to-collector waste oil. While only 13% of collectors get any waste oil from other collectors (which represents only 2% of their total gallonage), 41% of collector/processors get waste oil from other (presumably smaller) collectors.

-- There are other differences as well. While only 10% of collectors list pipelines as a source, more than one-third of collector/processors list pipelines as a source. And somewhat higher percentages of collector/processors use railroad, marine and oil spill sources.

TABLE D-2

Amounts of Waste Oil Collected from Sources
(With Estimate of Total Waste Oil Collected)

Q. 4: We would like to know what types of businesses you collect waste oil from. Do you collect waste oil from (TYPE OF BUSINESS)? IF YES -- How many gallons per month do you collect from (TYPE OF BUSINESS)?

Sources	Collectors		Collector/Processors	
	% Who Collect	Gallons/Month[1]	% Who Collect	Gallons/Month[2]
	(61)	(1,621,000)	(39)	(16,172,000)
Service stations and new car dealers	79%	58%	74%	18
Pipelines	10%	*	38%	8
Car or truck fleets	57%	8	64%	4
Railroads	28%	4	36%	1
Marine sources	36%	2	44%	6
Industrial users	89%	26	82%	39
Other waste oil collectors	13%	2	41%	23
Oil spills	7%	*	10%	*
Other[3]	--	--	13%	*

---

*Less than .5%

[1] Total gallons reported was 3,531,000 gallons/month. The sources of only 1,621,000 gallons/month could be broken down.

[2] Total gallons reported collected was 19,114,000 gallons/month. The sources of only 16,172,000 gallons/month could be broken down.

[3] Such as: fire department, oil company, airlines, foundries.

COLLECTOR/PROCESSORS OPERATE MUCH LARGER-SCALE COLLECTION BUSINESSES THAN COLLECTORS DO.

Collector/processors, on the average, maintain larger fleets of trucks.

-- Nearly 40% of all collectors have only one truck, and less than half of collectors have two or more trucks (Table 3).

-- The average number of trucks per collector is three.

-- By contrast, 41% of collector/processors have five or more trucks, and no collector/processors have only a single truck, although 21% rely entirely on outside contractors for their oil collecting. The average number of trucks per firm is seven.

The same trend is also seen in data measuring total truck capacity of firms from the two groups.

-- Nearly 60% of all collectors have a total truck capacity of 5,000 gallons or less. Only 13% of collectors have capacity exceeding 10,000 gallons.

-- Again, the collector/processors are much greater in their collection capacity. Only 10% have total truck capacity of 5,000 gallons or less (none have less than 2,500), and more than 50% have a total truck capacity exceeding 10,000 gallons.

The average collector/processor, then, has more trucks and more truck collection capacity (in gallons) than does the average collector.

TABLE D-3

Trucks and Truck Capacity

Q. 3: How many trucks do you use to collect waste oil and how many gallons does each truck hold?

Number of Trucks	Collectors (61)	Collector/ Processors (39)
5 or more	21%	41%
3-4	23	28
2	18	10
1	38	--
0	--	21[1]
Average number of trucks per firm	3	7

Total Capacity of Trucks	Trucks		Gallons	
	C/P*(31)[1]	Collectors (61)	C/P*	Collectors
(In thousands of gallons)			(957,000)	(469,000)
Over 20	23%	8%	74%	45%
15.1 - 20	13	--	8	--
10.1 - 15	19	5	8	8
5.1 - 10	35	30	9	30
2.5 - 5	10	21	1	9
Under 2.5	--	36	--	9

---

*C/P denotes Collector/Processors.

[1] Although eight of the 39 collector/processors do not have any collection capacity of their own, they do have a working relationship with collectors.

MOST COLLECTORS AND COLLECTOR/PROCESSORS PICK UP WASTE OIL FROM SOURCES WITHIN 100 MILES OF THEIR PLACE OF BUSINESS.

Widest ranging collector/processors usually exceed a collection range of 200 miles while widest ranging collectors cover 100 - 200 miles range.

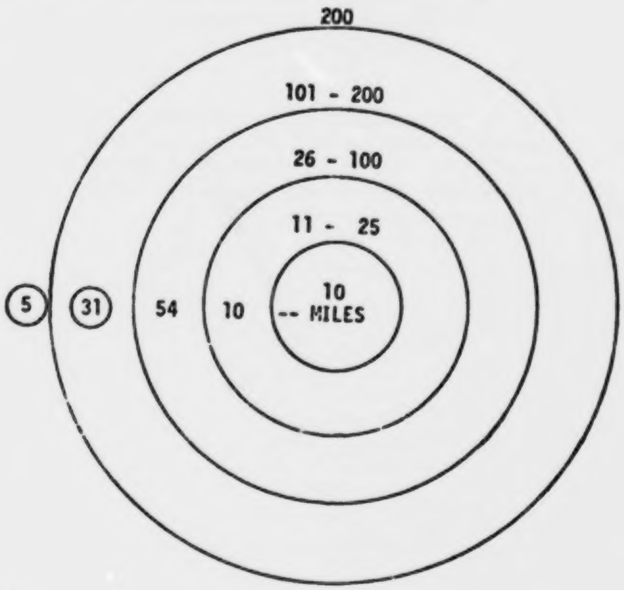
- 64% of all collectors pick up waste oil at distances of from 26 to 100 miles from their place of business: one-third pick up oil at distances exceeding 100 miles. (Table 4)
- 51% of collector/processors pick up waste oil at distances of from 26 to 100 miles; 41% from distances exceeding 100 miles.

At collection ranges over 100 miles differences between the two groups appear, While collectors and collector/processors differ greatly in their scales of operations, such as number and capacity of trucks and breadth of sources, only minor differences exist in area range they collect from.

TABLE D-4

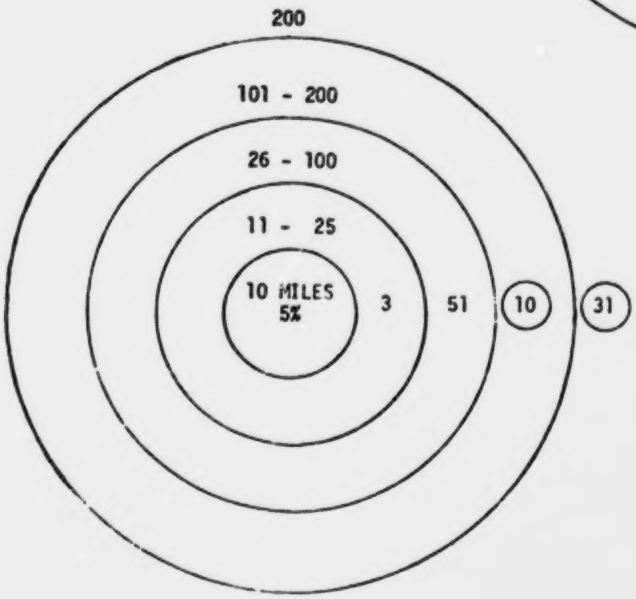
Collection Radius

Q. 1: What approximate radius, in miles, does your firm collect oil in?



Collectors (61)

Percent of firms who collect
in each radius zone.



Collector/Processors(39)

Percent of firms who collect
in each radius zone.

WASTE OIL COLLECTORS OPERATE MAINLY INTRA-STATE -- COLLECTOR/PROCESSORS TEND TO COLLECT MULTI-STATE.

-- About two-thirds of all collectors offer intra-state collection only, and only 3% collect waste oil from five or more states (Table 5).

-- Of those collector/processors with their own trucks, more than three-quarters of them collect in three or more states.

As in the cases of other indices, collector/processors run larger collection services than do collectors. Collector/processors, on the average, collect waste oil from more states than do collectors -- a statistic that also correlates with the greater number of trucks and truck capacities which the collectors/processors have.

TABLE D-5

Intra-and Inter-State Collection

Q. 2: Please tell me the names of the states in which you collect waste oil.

	Collectors (61)	Collector/Processors (31)*
Collect in 5 or more states	3%	48%
3 or 4 states	15	32
2 states	18	13
Intra-state collection only	64	6

---

*Although eight of the 39 collector/processors do not have any collection capacity of their own, they do have a working relationship with collectors.

MOST OF THE STORAGE FACILITIES OF WASTE OIL COLLECTORS WHO HAVE THEM, HOLD LESS THAN 500,000 GALLONS OR LESS CAPACITY.

-- 72% of all collectors with storage have a total storage capacity of 500,000 or less gallons and 4% have capacity of more than 1.5 million gallons (Table 6).

-- Storage facilities of collector/processors are somewhat larger as would be expected considering their greater need for storage tanks. One-third have storage capacity exceeding one million gallons, although nearly half of all collector/processors store 500,000 gallons or less.

-- While a small proportion of collector/processors refused to give out any data on their storage capacities, no collectors refused to supply this data.

TABLE D-6

Storage Facilities of Collectors

Q. 8: What is the total capacity of your storage facilities in gallons?

Total Capacity of Storage Facilities (in gallons)	Collectors with Storage (25)	Collector/ Processors (39)
Over 1,500,000	4%	13%
1,000,001 - 1,500,000	--	18
500,001 - 1,000,000	24	15
2,001 - 500,000	72	49
Under 2,000	--	--
Refused	--	5

NOT ALL STORED WASTE OIL IS PROCESSED OR REREFINED -- SEVERAL ALTERNATIVE USES ARE FOUND FOR IT, PARTICULARLY BY COLLECTORS.

Although a majority of collectors do transport some of their waste oil to other collectors or processors, much of the waste oil is disposed of in other ways. Comments of collectors indicate that alternative uses become feasible if:

(1) Suitable economic incentives are available from alternative uses.

(2) Transporting waste oil to other collection or processing facilities is particularly time consuming and expensive.

-- Collectors sometimes use their waste oil for road oil or dust control, even though several states now have outlawed this practice (Table 7).

-- Half of collectors also use waste oil as fuel, while only 16% use a settling tank without any further treatment.

-- Out of all the waste oil picked up by collectors, though, 45% is usually taken to another collector or processor -- 29% is used for fuel and another 22% is used for road oil or dust control.

A clear implication emerges -- most of the waste oil which is eventually processed and/or refined is oil which is collected by collector/processors and not by collectors.

-- A far smaller percentage of collector/processors use their waste oil for non-processed applications. Only 36% use any of their oil for fuel, representing only 7% of total oil gallonage and only 21% of the firms use their waste oil for road oil or dust control.

-- In addition, only 3% of collector/processors use waste oil as motoroil.

TABLE D-7

Uses of Stored Waste Oil, in Gallonage

Q. 9: What do you do with the waste oil when you remove it from storage? First, do you use it for road oil or dust control?

Q. 10: How many gallons per year do you (USE)?

	Collectors with Storage		Collector/Processors	
	% Who Use	Gallons/Year	% Who Use	Gallons/Year
	(25)	(3,106,000)	(39)	(51,480,000)*
Use for road oil or dust control	60%	22%	21%	1%
Use for fuel	48%	29	36%	7
Take to another collector or processor	56%	45	8%	--
Put in settling tank -- that is settling without any other treatment	16%	--	15%	2
Take to your own processing or rerefining plant	--	--	100%	88
Use for motoroil	--	--	3%	2
Other	12%	3	10%	--

---

*In this table, as in similar tables, gallonage bases are often smaller than percent-of-user bases. Many waste oil firms are sure of techniques and products used, but are unsure or unwilling to supply figures related to amounts.

WASTE OIL PROCESSORS

- Types and sizes of businesses
- Forms of treatment
- Types of oil produced
- Disposal of wastes
- Pollution control practices (water, air)
- National estimates of the waste oil industry
- Validity of the national estimates

WASTE OIL PROCESSORS

MOST WASTE OIL PROCESSORS ARE ALSO WASTE OIL COLLECTORS.

-- Of the processors studies, 79% collect as well as process waste oil (Table 8).

-- Most processors who only process and do not collect, mentioned that they use the services of many collectors and that most of these are small collection firms, with only one or perhaps a few trucks.

TABLE D-8

Types of Waste Oil Processors

	Processors (39)
Process oil but do not collect	21%*
Both collect and process waste oil	79%

---

*Although eight of the 39 collector/processors do not have any collection capacity of their own, they do have a working relationship with collectors.

WASTE OIL PROCESSORS DURING 1973 PROCESSED MORE THAN ONE MILLION GALLONS OF WASTE OIL.

-- Forty-nine percent processed between one and 24 million gallons during 1973 (Table 9).

-- Nearly one-third of all processors either refused to give out their 1973 processing figures or maintained they could not give an accurate figure. This question prompted a very large refusal rate.

TABLE D-9

Amount of Waste Oil Processed in 1973

Q. 12: How much waste oil would you estimate you processed in your facilities in 1973?

Estimated Amount of Waste Oil Processed in 1973 (in gallons)	Processors (39)
Over 24,000,000	3%
18,000,001 - 24,000,000	--
6,000,001 - 18,000,000	8
1,000,001 - 6,000,000	38
25,000 - 1,000,000	21
Under 25,000	3
Don't know	21
Refused	8

THE AVERAGE PROCESSING CAPACITY AMONG PROCESSORS IS APPROXIMATELY THREE MILLION GALLONS OF WASTE OIL PER YEAR.

-- One-third of all processors have a total annual processing capacity in the one-to-six million gallon range. More than three-quarters of all processors have an annual capacity between 25,000 and 24 million gallons (Table 10).

-- Fewer processors refused to provide capacity information than actual 1973 gallonage, but still 13% refused to give this information, or said they did not know their processing capacity.

TABLE D-10

Total Processing Capacity

Q. 11: What is the total capacity of your processing facilities in gallons per year?

Total Capacity of Processing Facilities (in gallons/year)	Processors (39)
Over 24,000,000	8%
18,000,001 - 24,000,000	8
6,000,001 - 18,000,000	13
1,000,001 - 6,000,000	31
25,000 - 1,000,000	26
Under 25,000	3
Don't Know	5
Refused	8

MANY PROCESSORS APPEAR TO BE UTILIZING THEIR PROCESSING FACILITIES AT 90% OF CAPACITY OR BETTER.

-- Actual processing in 1973 related to total processing capacity could not be computed for one-third of the processors in cases whether either of the two figures were refused (Table 11).

-- However, two in five are running their processing facilities at 90% or more of total capacity.

TABLE D-11

Estimated Processing (1973) Related to Total Processing Capacity

Q. 11: What is the total capacity of your processing facilities in gallons per year?

Q. 12: How much waste oil would you estimate you processed in your facilities in 1973?

Percent of Capacity	Processors (39)
90% or more	38%
75 - 89	--
50 - 74	5
25 - 49	13
Under 25	13
Not computable	31

---

*These figures were computed by dividing the mean within a total capacity range by the mean within the 1973 processing range. For this reason percentages-of-capacity figures are subject to some variation.

FILTRATION, SETTLING TANK, CLAY, DISTILLATION BATCH AND ACID ARE THE MOST COMMON OF ELEVEN TYPES OF WASTE OIL TREATMENT.

Of eleven types of waste oil treatment asked about specifically, each is used by at least 10% of the processors (Table 12).

-- In proportion to overall waste oil processed, filtration technique leads (16%), followed closely by acid and clay methods (each 15%), and flash drying and distillation batch (each 14% of total processing).

-- These treatments are used by 40% or more of the processors:

- 69% Filtration
- 56% Settling Tank
- 46% Clay
- 44% Acid
- 44% Distillation Batch

TABLE D-12

Processing Treatments Used

Q. 13: I am going to read you a list of processing methods. For each one could you please tell me whether or not you use this type of processing?

Q. 14: About how many gallons did you process using (TREATMENT) during 1973?

Treatments	Processors: Percent Who Use (39)	Processors: Gallons Processed in 1973 (125,575,000)
Filtration	69%	16%
Settling tank	56%	12
Clay treatment	46%	15
Acid treatment	44%	15
Distillation batch method	44%	14
Caustic treatment	26%	5
Chemical treatment	23%	10
Flash drying	23%	14
Centrifuge	18%	*
Silicate treatment	10%	--
Continuous vacuum distillation	10%	*
Other methods[1]	13%	*

---

*Less than .5%

[1] Such as: deep injection well, steam incinerate.

WHILE MOST PROCESSORS CAN NAME THE TYPES OF OILS THEY PRODUCE, VERY FEW HAVE KNOWLEDGE OF THE NUMBER OF GALLONS OF EACH THEY ACTUALLY PRODUCE.

-- #4 or #5 fuel oil, lube and road oils are the principal products of waste oil processors. Although other types of oil products are produced by fewer processors, all types are produced by at least 12% of the processors (Table 13).

-- Eighteen processors either refused to supply gallonage figures for each product they produce, or stated that they had no records available. Several other processors were able to supply gallonage figures for only a few of the products they produce.

TABLE D-13

Types of Processed Oils Produced

Q. 15: Next, I am going to read you a list of products. Please tell me whether or not you produce each type. First, take #2 fuel oil, do you produce #2 fuel oil?

Q. 16: How many gallons of (PRODUCT) did you produce in 1973?

	Processors	
Oils Produced	Percent Who Produce (39)	Gallons Produced in 1973 (50,942,000)[2]
#4 or #5 fuel oil	59%	29%
Lube oils	49%	39
Road oils	41%	7
#2 fuel oil	33%	3
Process oil	26%	8
Journal box oil	21%	4
#6 fuel oil	18%	7
Asphalt flux	13%	1
Farm oil	13%	*
Other methods[1]	18%	2

---

*Less than .5%

[1] Such as: rerefined oil mix with crude, grinding oil, edible, and burn it.

[2] The base for this question is 21, as 18 out of 39 processors did not supply the relevant data.

MOST PROCESSORS DISPOSE OF WASTE MATERIALS BY DUMPING THEM IN A LAND FILL.

- The only disposal method used by more than one-fourth of processors is dumping wastes into land fills -- and just over half of all processors say they use this single technique (Table 14).
- Only two processors dispose of wastes by injection into a deepwell, but this represents their only disposal technique and the gallonage is considerable on an annual basis.
- Of those processors who rely on biological treatment, nearly twice as many utilize public treatment rather than their own private biological facilities. Burning of wastes is also used by 23% of processors.

TABLE D-14

Methods of Disposing of Processing Wastes

Q. 17: How do you dispose of wastes, such as tank bottom, acid or caustic sludge, spent clay or distillation residue that develop in the course of processing?

Method	Processors Who Use (39)
Dump it in a land fill	56%
Use a public biological treatment	23%
Burn it	23%
Use your own biological treatment	13%
Dump it in a deepwell	5%
Dump it in the ocean	--
Other methods[1]	23%

---

[1] Such as: road oiling, take to special processor, give it to a trucking firm, sold for dust control, sell it, disposal service.

OIL-WATER SEPARATION AND SKIMMING ARE THE MAJOR FORMS OF WASTE WATER TREATMENT USED BY PROCESSORS.

-- Both oil-water separation and skimming are used by half of those processors questioned (Table 15).

-- Emulsion breaking, filters, biological treatment, and other methods (including silica sand, ammonia, and acid treatment) are each also used by at least 20% or more of the processors.

-- Many processors did not reply to this question and others were defensive. Several qualified their replies by outlining the regulations of their state pollution agencies. Three processors even stated that no waste water pollution was possible from their operation and that, for this reason, they perceived no rationale for following any protective course of action.

TABLE D-15

Waste Water Treatment Methods

Q. 18: What about waste water treatment?

Method	Processors Who Use (39)
Oil-water separation	49%
Skimming	46%
Filters	36%
Emulsion breaking	23%
Biological treatment, such as trickling filter or activated sludge	21%
Centrifuge	13%
Activated carbon	5%
Other methods[1]	21%
No answer[2]	15%
Refused	5%

---

[1] Such as: ammonia, take to special processor, silica sand, acid treatment.

[2] Three of these six processors insisted their industry causes no water pollution and do not, therefore, use any waste water treatment method.

PROCESSORS WERE EVEN MORE DEFENSIVE WHEN ASKED TO DESCRIBE THEIR AIR POLLUTION CONTROL SYSTEMS.

-- Scrubbing (33%) and incineration (33%) are the major forms of air pollution control utilized by waste oil processors (Table 16).

-- Other methods are seldom used. Those in the "other" category (10%) include: ammonia, wet scrubbing, coils, complete air-pollution enclosures.

-- More than one-third of all processors asked this question either did not answer or stated that they use no air pollution control techniques. Again defensive on this topic, seven processors stated that their type of business creates no form of air pollution and that, therefore, no control methods are in fact needed.

TABLE D-16

Methods of Air Pollution Control

Q. 19: What about air pollution control?

Form of Control	Processors Who Use (39)
Scrubbing	33%
Incineration	33%
Bag filters	5%
Electro-static precipitator	--
Other methods[1]	10%
No answer[2]	38%

---

[1] Such as: ammonia, wet scrubbing, coils, complete air pollution enclosure.

[2] Seven of the fifteen processors insisted their industry causes no air pollution, therefore no controls are needed.

COMPUTATION AND VALIDITY OF THE NATIONAL ESTIMATES

On Table 17 are our national estimates of the waste oil industry, on several important dimensions. Although each has been arrived at by means of an objective statistical procedure, the reader should keep in mind various factors affecting the national estimates.

All estimates are based on the data we collected for waste oil firms within our national probability sample areas. The information from these 103 areas was weighted up to represent a national estimate. While the Response Analysis probability sample is based on demographic statistics from the 1970 Census, the waste oil industry may not totally coincide geographically with overall population distributions, although our sample is drawn heavily from urban areas where waste oil firms seem to locate.

Data were weighted in other ways as well. Although Response Analysis developed lists of waste oil firms from telephone yellow page directories, many firms may not have phone listings and directories are only published annually. For this reason, we weighted up the number of firms on the basis of additional names we got from the licensing agencies of three states -- Massachusetts, Texas and Maryland.* We also weighted the estimates to account for differences among the areas which each sample area represents and also to account for different completion rates among the respondents contacted in each area. These weighting systems are explained in detail in the Appendix.

The reader should also bear in mind that only a small number of firms agreed to participate -- 61 collectors and 39 collector/processors, and that the validity of national estimates based on this small number of cases is reduced. The reader should also realize that the validity will decrease with time. As stated earlier, the waste oil industry is affected by many external factors, and many changes and fluctuations are probable in the future. While our national estimates may be valid for a short period of time, no projection of their accuracy can be stated for extended periods of time.

National estimates of amount of oil processed in 1973 and the capacity of processing facilities were computed in terms of ranges, although we also compute a median "best estimate." In each case, we multiplied the estimated number of firms of a certain size or capacity times the minimum and maximum production or capacity figures within that firm's answer category. Data for all firms were then summed to provide the estimated total minimum and maximum figures. We then computed the median of the two figures as the best overall estimate. The final mean estimates are calculated to the nearest one thousand gallons. In the case of unbounded answer categories ("over 24 million" and "under 25,000"), we used the anchor figure for one extreme and a figure of plus-or-minus 10% as the other extreme figure for the answer category.

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*We were only able to calibrate the differences between the phone list and state license lists for these three states. This weight was then applied to all states. Massachusetts officials were able to supply us with the names of 17 additional waste oil firms -- Texas supplied seven more, and Maryland supplied only one.

TABLE D-17

NATIONAL ESTIMATES OF THE WASTE OIL INDUSTRY

Number of Collectors	260
Number of Collector/Processors	163
Gallons Collected Per Month	136,681,925

Amount Processed During 1973 (in gallons)

	ESTIMATED NUMBER OF FIRMS	MINIMUM	SUB-TOTALS	MAXIMUM	SUB-TOTALS
Over 24,000,000	8	24,000,001	192,000,000	26,400,000	211,200,000
18,000,001 - 24,000,000	0	18,000,001	NONE	24,000,000	NONE
6,000,001 - 18,000,000	15	6,000,001	90,000,000	18,000,000	270,000,000
1,000,001 - 6,000,000	86	1,000,001	86,000,000	6,000,000	516,000,000
25,000 - 1,000,000	45	25,000	1,125,000	1,000,000	45,000,000
Under 25,000	9	22,500	202,500	24,999	224,991
		MINIMUM TOTAL =	369,327,000	MAXIMUM TOTAL =	1,042,425,000

MEDIAN ESTIMATE = 705,877,000

Capacity of Processing Facilities (in gallons)

Over 24,000,000	13	24,000,001	312,000,000	26,400,000	343,200,000
18,000,001 - 24,000,000	11	18,000,001	198,000,000	24,000,000	264,000,000
6,000,001 - 18,000,000	16	6,000,001	96,000,000	18,000,000	288,000,000
1,000,001 - 6,000,000	82	1,000,001	82,000,000	6,000,000	492,000,000
25,000 - 1,000,000	34	25,000	850,000	1,000,000	34,000,000
Under 25,000	7	22,500	157,500	24,999	174,993
		MINIMUM TOTAL =	689,008,000	MAXIMUM TOTAL =	1,421,375,000

MEDIAN ESTIMATE = 1,055,192,000

In making a national estimate of the amount of waste oil processed during 1973, the following method of computation was used:

- We first estimated the number of firms in each size category. The number of firms in each category from our sample was weighted up to a national estimate of firms.

- For each processing category, the estimated number of firms was multiplied times both the minimum and maximum processing figures for that category. For instance -- we estimate there are eight firms which processed more than 24,000,000 gallons of waste oil during 1973. Eight was then multiplied times 24,000,001 gallons (the minimal figure for the category) and also times 26,400,000 (24,000,000 plus 10%) for the maximum amount.

- We then summed total estimated minimum and maximum production for 1973. We then took the median of these two figures as our best estimate of waste oil processed during 1973.

The same method of computation was also used in estimating national waste oil processing capacity.

FUTURE INDUSTRY PROSPECTS

- Trends foreseen by waste oil firms
- Reasons for them

FUTURE INDUSTRY PROSPECTS

Collectors and collector/processors were asked at the conclusion of the interviews to discuss the growth or decline of their business, to speculate on the causes of the growth or decline, and to predict future trends in the industry.

Growth and Decline in the Waste Oil Industry

Half of all collectors (49%) feel there has been no change recently in their business, while nearly one-third (28%) feel their business has actually been declining.

By contrast, two-thirds (67%) of collector/processors say they have growing businesses, and only one in five (21%) report declining business.

Thus, market share within the waste oil industry is changing. Most collector/processors are growing, at the expense of collectors who are experiencing either no growth or actual decline.

TABLE D-18

Q. 20: During the last year or so has your business been growing, declining, or has there been no major change in your size?

	Collectors (61)	Collector/Processors (39)
Growing	23%	67%
Declining	28	21
No change	49	13

The vefbatim comments of company spokesmen were recorded. Although these comments are provocative, and illustrative of trends in the waste oil industry, they were elicited from unstructured questions and have not been quantified to statistically represent the entire universe of waste oil collectors and collector/processors. The verbatim comments, grouped typically, are presented on pages 46, 47 and 48.

COLLECTORS VERSUS COLLECTOR/PROCESSORS: THE ISSUES ARE THE SAME BUT PERSPECTIVES ARE DIFFERENT.

Company spokesmen consistently mentioned the same five central issues facing their industry: the energy crisis, environmental pollution and governmental regulations, changes in equipment and technology, internal business factors, and the competition between collectors and collector/processors.

But in terms of viewpoint, collectors and collector/processors differ greatly. While most collector/processors feel their businesses are growing and see continued future growth, a majority of the collectors say they are experiencing a decline or period of no growth in their businesses, and they foresee a continued decline for their sector.

The two groups also differ on their viewpoints on specific industry issues, particularly in reference to the energy crisis and environmental pollution and governmental regulation.

We enclose the verbatim comments of industry spokesmen to document the five key industry issues and trends.

1. The Energy Crisis

It appears that all firms are well aware of some of the impact the oil shortage has had on their industry. But while collector/processors see the oil shortage as a positive "growth" force on their business, many collectors have been seriously hurt by the shortage. This seems entirely consistent with data previously discussed -- collectors depend on crankcase oil as their major source, while collector/processors have a much wider collection base.

Business growing . . .

Due to the shortage of crude oil, many of our customers who are unable to get new lube oil now buy it from us, whereas they didn't before. (C/P)*

Business picked up after the energy crisis. Before, we couldn't get any money for fuel oil, but now, with the big demand for fuel oil, we get more money. (C/P)

Business will continue to grow as long as the energy crisis exists. You can't sell recycled oil when new is available. So, if the crisis exists, we will grow. (C/P)

The supply of used motor oil will decline, but I think that this will be offset by the use of rerefined oil. I look for a good future in sales. I am very optimistic. (C/P)

Business declining . . .

It is the gas shortage. It has depleted our income. There is no longer such a thing as waste oil. Without that we cannot run a business. (C)**

In the last two years there has been pretty much the same pattern of people changing their oil. We have lost some of the service station clients in the city, but we have gotten new accounts at the newer suburban-type garages. The last few years, overall, have been down from five to ten years ago -- people go longer between oil changes. (C)

---

*C/P denotes Collector/Processor.

**C denotes Collector.

2. Concern Over Environmental Pollution and the Proliferation of Governmental Regulations Covering the Waste Oil Industry.

Many industry spokesmen have seen basic changes in their collection and processing methods. Many others are bothered by the increased role of government in overseeing and regulating their industry.

Business growing . . .

We cooperate with the environmental people rather than fight them. We are not scavengers looking for business. (C/P)

People are more aware that reclamation exists. There is a lot of economic incentive. Ecology and economy are big words. (C/P)

Great future, depending on rules and regulations and the financial tax incentive. (C)

Business declining . . .

Because of the new off-the-road tax, and because of labeling. (C/P)

I don't see a bright future; the oil crisis is going to change a lot of things. The ingenuity of the government will make the whole situation very competitive, hurting the small businesses. (C)

It all depends on Uncle Sam. The biggest problem is disposing of waste. If the County stops us from dumping where we do now, we will be out of business. (C/P)

3. New Equipment and Technologies in the Waste Oil Industry.

Business growing . . .

Good. It is a small company, but I feel with the new processes being developed, we have no place to go but ahead. (C/P)

Great future in the recovery of waste oil as lubricating oil. (C/P)

An economical method to make fuel oil is now available. People can't take to landfill anymore. (C/P)

New processes such as regeneration of acid -- an excellent new process. (C/P)

We have a vacuum truck, which is fairly unknown in the northwest, and once people become more aware of its capabilities, we see our business growing. (C)

Business declining . . .

We are running out of landfills. It is getting too costly to dispose of the materials in the landfills. (C/P)

4. Internal Business Practices and Factors.

Business growing . . .

Effective manager and the new owner. (C/P)

Service -- our business is growing because we give better service. (C)

Because I hustle for my business; I don't sit back and wait for it to come to me. I go get new business all the time. (C)

We work harder. (C)

We do very good work; we grew three times as much. We are building, buying more equipment and hiring more people. (C)

5. Competition between Collectors and Collector/Processors.

Spokesmen's comments also reveal that a further dimension exists, reflected in the collector-collector/processor dichotomy. This dimension is big business versus the small business. While most collector/processors maintain larger-scale operations with more capital to invest in new equipment, most collectors maintain much smaller businesses and are less well-equiped to meet increasing competition within the waste oil industry.

Business declining . . .

It is going to get tough; less oil and more people out to get it. (C)

Business should grow, but the smaller guys will drop out. The energy crisis has helped waste oil products and dealers, but a guy needs a bigger capacity and more clients in the future. (C)

Competitive government refineries that have put more collectors on the street. They borrowed money from the government to increase their business, and now they have more collectors out, which is affecting my business. (C)

METHODOLOGY

- Sample design
- Interviewing experience
- Questionnaire

SAMPLE DESIGN

The sample for this study was drawn from the hundreds of waste oil collectors and processors in the coterminous United States.

No complete list of all waste oil collectors and/or processors exists from which the sample could be drawn. Only a few states require this type of business to have permits. And no federal registration is required. Therefore, our job was to compile a list of these businesses from which to sample.

The sequence of steps used in the development of the sample included:

- Selection of a national sample of 103 primary areas, counties or groups of counties, stratified by geographic region, type of community and other population characteristics.
- Obtaining all yellow pages telephone directories in all of the counties in the 103 primary areas.
- Compiling a list of all waste oil handlers that are listed in the yellow pages directories.

Several steps were taken to supplement this list of waste oil businesses which are as follows:

- Contacting individuals in and/or involved in some aspect of the waste oil business to obtain additional information.
- Writing to all the members of the Association of Petroleum Rerefiners to obtain additional names.
- Asking each interviewed firm in the process of interviewing to give additional names.
- Obtaining the state lists of waste oil handlers from the Water Quality Resources Offices of Texas, Massachusetts and Maryland.

Details on each of these steps is provided in the following sections.

Selection of Sample Areas for National Sample

Primary areas were selected as follows:

The entire area of the coterminous United States was first divided into approximately 1,140 primary sampling units (PSU's). Each PSU is a well defined geographic unit, usually a county or a group of counties with a minimum population of 50,000 in 1970. PSU's are of two general types: (1) metropolitan areas, or parts of metropolitan areas; and (2) other areas.

Thirty-eight large PSU's were included in the sample as self-representing primary areas. These include the 25 largest metropolitan areas in the United States.

All other PSU's were grouped into 65 strata, with an average stratum population of approximately 2,000,000 persons in 1970. Basic criteria used in the stratification procedure were:

- Geographic division (within a stratum all PSU's are in the same Census geographic division).
- Metropolitan or nonmetropolitan character (with the exception of a few counties, strata consist entirely of metropolitan areas or entirely of other counties).

These two stratification features are employed in regional and community-size analysis.

Additional stratification criteria included population density, rate of population growth, and industrial characteristics.

One PSU was selected with probability proportionate to population size from each of the 65 strata that included two or more PSU's.

Each of the 103 primary areas (38 selected as self-representing areas, plus 65 selected as a result of the stratification procedure) is a relatively heterogeneous area. Most include city, town suburban and rural residents. Some are primarily small towns and rural, but are several counties in size.

Compiling a List From the Yellow Pages Directories

Yellow pages directories were obtained for all counties in the 103 PSU's. To compile a list of names, several headings in each directory were referred to and names in each section were recorded. Those headings are as follows:

Oils - waste

Waste - oil

Waste reduction & disposal service - industrial

Tank cleaning

Ecological conservation

Every name and telephone number was reviewed and compared with others in each primary sampling unit and any duplicates were removed. Also, each address was checked to make sure that the waste oil firm physically was located in a sample county. This was done because in many cases yellow page directories cover wider areas than do the white pages.

Individuals Contacted to Obtain Additional Information

Individuals in the waste oil business and individuals who have dones studies of the waste oil business were contacted to try to supplement the list of waste oil collectors and/or processors from the yellow pages directories. Those contacted were:

> Several processors in the New Jersey and Pennsylvania areas to ascertain registration requirements or practices of collectors and processors with government agencies or with associations. We found no association exists for this particular group. Registration is required in some states, but not all.
>
> The U. S. Department of Interior, Bureau of Mines, who sent us a copy of their study on waste oil recycling. From this a comprehensive list of rerefiners and contact names of people knowledgeable about waste oil was made available.
>
> Messrs. Richard Finocchi and John Williams of Resource Planning Associates in Cambridge, Massachusetts, have done several studies on waste oil and told us which states require registration and permits and from which state office permits are obtained.

Contacting Members of Association of Petroleum Rerefiners

Response Analysis sent letters to the 45 names of commercial rerefiners on the list received from the Bureau of Mines. This letter asked for their help in building Response Analysis' industrial sample by providing us with names of waste oil processors and collectors. Five of those letters were returned because the company was no longer in business. Of those forms returned completed, 22 names were given. These names were checked against the list and any additional names were added.

Obtaining Lists From State Governments

From the Water Quality Control Offices of Texas, Maryland and Massachusetts the lists of registered waste oil handlers were requested.

These lists served two functions. The first was to provide additional names for the locations that are in these states. The second and more important function was to compare the state lists of names with the yellow pages directory list of names. By doing this, locations could be weighted up in the national projections to compensate for the differences between the two.

Waste Oil Sample Weighting

In developing the national projections, three weight factors were applied to the data:

1. A weight factor equal to the reciprocal of the probability of selection of each PSU from its stratum. For self-representing PSU's (the top twenty-five metropolitan areas) this weight factor was 1. For smaller metropolitan areas and nonmetropolitan PSU's the weight factors were higher.

2. A weight factor to adjust for the fact that some eligible respondents refused to be interviewed or were unavailable after several calls. This weight factor was computed separately for each PSU and was equal to the number of eligible respondents divided by the number of completed interviews in that PSU.

3. A third weight factor to compensate for the fact that some collectors and processors were not listed in the yellow pages. Complete listings of collectors and processors were obtained for three states. These listings were compared with the yellow page listings for those states. Based on that comparison, a weight factor of 1.71 was applied to all interviews to adjust for unlisted collectors and processors.

The final weight factor used for each interview was the product of the above three weight factors.

INTERVIEWING EXPERIENCE

Interviewing was done by a WATS telephone interviewing service. Each interviewer who worked on the study was briefed on the questionnaire. Interviewers were instructed on the difficulty of reaching many of the respondents. They were told to leave a message with the waste oil firm to call Response Analysis collect, if they were unable to directly contact the correct respondent. A letter from Response Analysis explaining the nature of the study and that Response Analysis was conducting the study for the Environmental Protection Agency was sent to each organization before interviewing began. A sample of the letter is bound in this report. Each respondent was assured through the letter and the interviewer that individual answers would be kept in strict confidence and results would be available only as a statistical compilation:

The results of the interviewing were as follows:

TOTAL NAMES	285
Completed interviews	100
Refused	43
*Do not collect waste oil	32
Direct contact with respondent not made (Response Analysis' number given -- never called back)	44
No longer in business	32
No answer, six callbacks made	25
Duplicate	9

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*Although these firms had listings in the waste oil categories in yellow page telephone directories, they have either changed their operation or else their type of business can be subsumed under no other directory heading.

Response Analysis

Research Park, Route 206
Princeton, New Jersey 08540
(609) 921-3333

March, 1974

Dear Sir:

Response Analysis is a private research organization, specializing in attitude, social, and marketing research. Currently we are conducting a nationwide study for the Edison, New Jersey Laboratories of the Environmental Protection Agency on waste oil collection and processing.

Your firm is one of a randomly selected group of waste oil collection and/or processing businesses throughout the country who are being surveyed to better understand the contribution being made by such firms to our present energy needs. Your participation will take only a little time by telephone but is essential to the study's success.

Please be assured that your individual answers will be kept in strict confidence. Neither your company's name or your name will be identified with your responses in any manner. Results will be available to the Environmental Protection Agency only in summary form and not for any individual or company.

Our representative will phone you during the next week or so to get your opinions. If you have any questions, please call me at (609) 921-3333, or Leo McCarthy, Assistant Director of the Edison Laboratories at (201) 548-3347.

Thank you for your cooperation.

Sincerely,

Paul A Scipione

Paul A. Scipione, Ph.D.
Research Associate

erl

Time Began:__________

NATIONAL WASTE OIL COLLECTORS AND PROCESSORS SURVEY

Hello, I am__________ from Response Analysis Corporation in Princeton, New Jersey. Recently you were sent a letter telling you about a survey on waste oils and asking your cooperation. Did you receive that letter? (IF NOT: USE SCRIPT TO EXPLAIN PURPOSE OF SURVEY)

I would just like to ask you some questions which will take only a few minutes. (IF RESPONDENT IS TOO BUSY, MAKE APPOINTMENT TO CALL BACK)

1. What approximate radius, in miles does your firm collect oil in?

1 10 MILES OR LESS
2 11 TO 25 MILES
3 26 TO 100 MILES
4 101 TO 200 MILES
5 OVER 200 MILES
6 OTHER: (SPECIFY):______________
7 DON'T KNOW

2. Please tell me the names of the states in which you collect waste oil.

1 ALABAMA
2 ARIZONA
3 ARKANSAS
4 CALIFORNIA
5 COLORADO
6 CONNECTICUT
7 DELAWARE
8 FLORIDA
9 GEORGIA
10 IDAHO
11 ILLINOIS
12 INDIANA
13 IOWA
14 KANSAS
15 KENTUCKY
16 LOUISIANA
17 MAINE
18 MARYLAND
19 MASSACHUSETTS
20 MICHIGAN
21 MINNESOTA
22 MISSISSIPPI
23 MISSOURI
24 MONTANA
25 NEBRASKA
26 NEVADA
27 NEW HAMPSHIRE
28 NEW JERSEY
29 NEW MEXICO
30 NEW YORK
31 NORTH CAROLINA
32 NORTH DAKOTA
33 OHIO
34 OKLAHOMA
35 OREGON
36 PENNSYLVANIA
37 RHODE ISLAND
38 SOUTH CAROLINA
39 SOUTH DAKOTA
40 TENNESSEE
41 TEXAS
42 UTAH
43 VERMONT
44 VIRGINIA
45 WASHINGTON
46 WEST VIRGINIA
47 WISCONSIN
48 WYOMING

3. How many trucks do you use to collect waste oil and how many gallons does each truck hold?

NUMBER OF TRUCKS__________

GALLONS______________

4. We would like to know what types of businesses you collect waste oil from. Do you collect waste oil from (TYPE OF BUSINESS)? IF YES -- How many gallons per month do you collect from (TYPE OF BUSINESS)? (IF NO GO TO NEXT TYPE OF BUSINESS)

(INTERVIEWER: ASK FOR EACH TYPE A-H)

	Q. 4			Q. 5	
	COLLECT FROM		GALLONS/MONTH	NUMBER COLLECTED FROM	
	YES	NO		BY CONTRACT	BY CALL
a. Service stations and new car dealers	1	2			
b. Pipelines	1	2			
c. Car or truck fleets	1	2			
d. Railroads	1	2			
e. Marine sources	1	2			
f. Industrial users	1	2			
g. Other waste oil collectors	1	2			
h. Any other businesses (SPECIFY):	1	2			
	1	2			

ASK Q. 5 FOR EACH TYPE COLLECTED FROM)

5. How many (TYPE OF BUSINESS) do you collect from on a contract basis, and how many others on a per-call basis?

6. Do you have your own storage facilities for the oil you collect, or do you only transport the oil to another waste oil collector or processor?

1 HAVE STORAGE FACILITIES -- SKIP TO Q. 8
2 TRANSPORT TO COLLECTOR OR PROCESSOR

7. Could you tell me the name and address of the collector or processor you take your waste oil to?

____

____

____

IF Q. 7 ASKED, SKIP TO Q. 20

8. What is the total capacity of your storage facilities in gallons?

1 UNDER 2 THOUSAND GALLONS
2 OVER 2 THOUSAND - 5 HUNDRED THOUSAND GALLONS
3 OVER 5 HUNDRED THOUSAND - 1 MILLION GALLONS
4 OVER 1 MILLION - 1 MILLION 5 HUNDRED THOUSAND GALLONS
5 OVER 1 MILLION 5 HUNDRED THOUSAND - 2 MILLION GALLONS

9. What do you do with the waste oil when you remove it from storage. First, do you use it for road oil or dust control? (INTERVIEW: READ REMAINING METHODS b-f)

	Q. 10		
	USE	DON'T USE	Q.11 AMOUNT
Do you:			
a. Use for road oil or dust control	1	2	________
b. Use for fuel	1	2	________
c. Take to another collector or processor	1	2	________
d. Put in settling tank -- that is settling without any other treatment	1	2	________
e. Take to your own processing or rerefining plant	$\boxed{1}$	2	________
f. Are there any other things you do with it?	1	2	________

SPECIFY:________________________

(ASK Q. 10 FOR EACH USE INDICATED

10. How many gallons per year do you (USE)?

INTERVIEWER: IF RESPONDENT TAKES ANY OIL TO OWN PROCESSING OR REREFINING PLANT, METHOD e, CONTINUE WITH QUESTION 11. IF RESPONDENT DOES NOT TAKE TO OWN PROCESSING OR REREFINING PLANT SKIP TO QUESTION 20.

11. What is the total capacity of your processing facilities in gallons per year?

1 UNDER 25 THOUSAND GALLONS
2 OVER 25 THOUSAND - 1 MILLION GALLONS
3 OVER 1 MILLION - 6 MILLION GALLONS
4 OVER 6 MILLION - 18 MILLION GALLONS
5 OVER 18 MILLION - 24 MILLION GALLONS
6 OVER 24 MILLION GALLONS
7 DON'T KNOW

12. How much waste oil would you estimate you processed in your facilities in 1973?

1 UNDER 25 THOUSAND GALLONS
2 OVER 25 THOUSAND - 1 MILLION GALLONS
3 OVER 1 MILLION - 6 MILLION GALLONS
4 OVER 6 MILLION - 18 MILLION GALLONS
5 OVER 18 MILLION - 24 MILLION GALLONS
6 OVER 24 MILLION GALLONS
7 DON'T KNOW

13. I am going to read you a list of processing methods. For each one could you please tell me whether or not you use this type of processing. First, caustic treatment, do you use caustic treatment?

Do you use:	Q. 13 USE METHOD	 DON'T USE METHOD OR DON'T KNOW	Q. 14 AMOUNT PROCESSED IN 1973 IN GALLONS
a. Caustic treatment	1	2	
b. Silicate treatment	1	2	
c. Chemical treatment	1	2	
d. Filtration	1	2	
e. Centrifuge	1	2	
f. Flash drying	1	2	
g. Distillation batch method	1	2	
h. Continuous vacuum distillation	1	2	
i. Acid treatment	1	2	
j. Clay treatment	1	2	
k. Settling tank	1	2	
l. Other methods (SPECIFY):			
____________________	1	2	
____________________	1	2	

ASK Q. 14 FOR EACH METHOD USED IN Q. 13

14. About how many gallons did you process using (TREATMENT) during 1973?

15. Next, I am going to read you a list of products. Please tell me whether or not you produce each type. First take #2 fuel oil, do you produce #2 fuel oil?

	Q. 15		Q. 16
	PRODUCE PRODUCT	DON'T PRODUCE PRODUCT	AMOUNT PRODUCED IN 1973
a. #2 fuel oil	1	2	________
b. #4 or #5 fuel oil	1	2	________
c. #6 fuel oil	1	2	________
d. Process oil	1	2	________
e. Asphalt flux	1	2	________
f. Lube oils	1	2	________
g. Road oils	1	2	________
h. Farm oil	1	2	________
i. Journal box oil	1	2	________
j. Other (SPECIFY):			
________	1	2	________
________	1	2	________

ASK Q. 16 FOR EACH PRODUCT PRODUCED IN Q. 15

16. How many gallons of (PRODUCT) did you produce in 1973?

17. How do you dispose of wastes; such as tank bottom, acid or caustic sludge, spent clay or distillation residue that develop in the course of processing?

Do you:	USE METHOD	DON'T USE METHOD	DON'T KNOW
a. Dump it in a land fill	1	2	3
b. Dump it in a deepwell	1	2	3
c. Dump it in the ocean	1	2	3
d. Use your own biological treatment	1	2	3
e. Use a public biological treatment	1	2	3
f. Burn it	1	2	3
g. Use any other method SPECIFY: ________	1	2	3

18. What about waste water treatment?

Do you use:	USE METHOD	DON'T USE METHOD	DON'T KNOW
a. Emulsion breaking	1	2	3
b. Oil-water separation	1	2	3
c. Skimming	1	2	3
d. Biological treatment, such as trickling filter or activated sludge	1	2	3
e. Centrifuge	1	2	3
f. Filters	1	2	3
g. Activated carbon	1	2	3
h. Any other method (SPECIFY):			
______________________________	1	2	3

19. What about air pollution control?

Do you use:	USE METHOD	DON'T USE METHOD	DON'T KNOW
a. Scrubbing	1	2	3
b. Incineration	1	2	3
c. Electro-static precipitator	1	2	3
d. Bag filters	1	2	3
e. Any other method (SPECIFY):			
______________________________	1	2	3

Finally a few general background questions to help us analyse the results. . .

20. During the last year or so has your business been growing, declining, or has there been no major change in your size?

1 GROWING
2 DECLINING
3 NO CHANGE -- SKIP TO Q. 23

21. What is the reason for the (growth/decline) in business?

22. What future trends do you foresee in your type of business?

23. How many terminals or storage facilities do you have in urban areas? How about rural areas?

URBAN AREAS ___________________

RURAL AREAS ___________________

24. How many fulltime employees do you have?

1 LESS THAN 10
2 11 - 50
3 51 - 100
4 101 - 150
5 150 - 200
6 OVER 200
7 DON'T KNOW

25. How many shifts do you operate?

1 ONE
2 TWO
3 THREE
4 OTHER (SPECIFY): ____________________________
5 DON'T KNOW

Thank you very much for your cooperation!

Time Ended: ______________

Length of Interview: __________

Respondent appeared
1 Very knowledgeable
2 Somewhat knowledgeable
3 Not very knowledgeable

Respondent was
1 Cooperative
2 Somewhat cooperative
3 Very uncooperative

Respondent's Name: ______________________

Title: ______________________

Company Name: ______________________

Business Address: ______________________

Business Telephone: ______________________

Interviewer Name: ______________________ Date: ____________

APPENDIX E

INDUSTRIAL SURVEY

SIC MAJOR GROUP 01 - Agricultural Production/Crops

Annual oil purchases and disposal practices were reported for one plant and related field operation.

Machine and Repair Shop

Service tractors, bulldozers, carts, and other field vehicle.

Type	Use	Annual Amount
Havoline Motor oil 30	---	100 cases (24 qts/case)
Marfax #1 Grease	---	50 drums (120 lbs/drum)
Series 3-LA330 oil	---	12,000 gallons
Randol C-hydraulic oil	field equipment hydraulic cylinders	
Series 1-SAE 30	---	12,000 gallons
URSA ED 30 oil	---	12,000 gallons

These oils are changed right in the field and dumped on the ground at the site (45,000 acres).

Oils Purchased for In-Plant Usage

Type	Use	Annual Amount
Klingfast Special Extra Light Oil	Lubricate main journals	80 drums (420 lbs/drum)
Klingfast 265-HW Lube Oil	Lubricate wheels for mills	8 drums (440 lbs/drum)
676-W Brooks Worm Gear Oil	Lubricate all worm gears	13 kegs (115 lbs/keg)
Texaco Regal, PC (R+O)	Lubricate speed reducers	120 drums (55 gal/drum)

Type	Use	Annual Amount
Texaco Regal G (R+O)	Lubricate speed reducers	30 drums (55 gal/ drum)
Texaco Regal A (R+O)	" "	15 drums (55 gal/ drum)
Texamatic Fluid	Hydraulic fluid	6 drums (55 gal/ drum)
Marfax MP-#2	Grease caps, bearings, shafts	30 drums (120 lbs/ drum)
Crater 2X Fluid	Hydraulic fluid	6 drums (415 lbs/ drum)
URSA LA3 SAE 40 Oil	Special lube oil	2 drums (55 gal/ drum)
Meropa #3	Lubricate speed reducers	1 drum (55 gal/ drum)
Meropa #8	" "	50 drums (415 lbs/ drum)

The oils from the speed reducers are changed, collected in drums and used without any processing for less demanding lubrication such as chains, gears, etc.

The other oils are dissipated in unknown ways, e.g. dripping on floors, getting in product (?), vaporizing, etc. Drips on floors wind up in drains, which used to go to drainage ditches. Presently the company is separating drains which receive pollutants and directing them to an impounding area.

SIC MAJOR GROUP 02 - Agricultural Production/Live-Stock

The company contacted has seven independent agricultural production (live-stock) operations. One typical operation reported that the only waste oils they generated were from the servicing of pickup trucks and power equipment. The crankcase oils, approximately 20 gallons per month, are collected in 55 gallon drums and used to lubricate high speed roller chains and open drive shafts on conveyer equipment.

SIC MAJOR GROUP 07 - Agricultural Services

The agricultural service company contacted has approximately 900-1000 employees at their main plant. Waste oils generated from their operations and the means of disposal are:

1. Lube and seal oil in ammonia refrigeration systems. They purchase about 55 gallons per month to makeup that which is disposed of by dumping down the drain. About 150 gallons per month additional are drained, filtered, allowed to vent the dissolved ammonia, and reused.

2. The plant purchases about 300 gallons per month of gear box, motor, compressor, and other drive system lube oils. Most of them leak out onto the ground. An estimated 100 gallons per month are drained off and dumped down the drain.

3. There are very small amounts of transformer oils involved. They are cleaned up and reused.

4. The fuel oil tank purges about 50 gallons per month of Bunker C or No. 6 oil which goes into a small lagoon. This is caused by a steam leak in a heating coil. Presently there are about 500 gallons of oil in the lagoon and it is in the company's interest to recover and use this oil.

5. Sludge from the fuel oil tank is removed once a year and buried in a local dump.

6. There are about 700 gallons per month of crankcase oils generated from the servicing of material haulers and industrial vehicles. These are stored in a 4,000 gallon underground tank and hauled away once a month by a local waste oil collector. There is no charge for the disposal service.

SIC MAJOR GROUP 79 - Amusement and Recreation Services Except Motion Pictures

Machine Shop

Generates about 25 gallons per week of waste lube and cutting oils. They collect them in a 1,000 gallon holding tank. Periodically it is picked up by a local waste oil collector.

On-Site Vehicles Maintenance Shop

Approximately 300 vehicles (trucks, buses, trains, etc.) are serviced (about 25 lube oil changes per week). The waste oils are collected and stored in the same tank as above.

Small Engine Maintenance Shop

Services lawn mowers, tractors, pumps, etc. Lube and hydraulic oils are put in 55 gallon drums and used for dust control purposes. Very small quantities of waste oils are involved.

Company Owned Gas Station

Services company cars. They reportedly accumulate less than 30 gallons per month. The oil is collected in 55 gallon drums and is used for fire training programs and dust control at a sanitary landfill site.

Central Energy Plant

Has two natural gas jet turbines for electricity followed by hot water boiler. The oils purchased for the plant are as follows:

1. Jet Engine Oil--consumption 40 gallons per year
2. Turbine Oil--consumption 200 gallons per year
3. Air Compressor Oil--consumption 75 gallons per year
4. Chiller Oil--consumption 100 gallons per year

5. General Lube Oil--consumption 200 gallons per year

Any waste oil is collected and put in the main waste oil storage tank to be hauled away.

SIC MAJOR GROUP 23 - Apparel and Other Finished Products Made From Fabrics and Similar Materials

All company vehicles are serviced at local service stations (40 cars and 20 trucks). An estimated 3,200 gals/year of sewing machine oil is purchased and used on gears in the sewing machines. The oil disappears onto fabrics or into the air, therefore, no disposal is needed. Approximately 600 gallons per year of hydraulic oil and 5 gallons per year of oil from compressors are dumped on an open lot behind the factory. Transformers are serviced under contract. There is no process water in this plant.

SIC MAJOR GROUP 75 - Automotive Repair Services and Garages

The company leases more than 10,000 each of short term rental cars, rental trucks, and long term lease cars. Sixty percent of the cars and all of the rental trucks are serviced at various company owned service areas throughout the U. S. The balance of the cars are leased from automobile manufacturers and serviced under contract.

The vehicles that are directly serviced by the company have the oil and oil filter changed every 6,000 miles. The average vehicle is run approximately 15,000 miles per month and is used for rental or lease purposes for 18,000-20,000 miles. It is then sold or returned to the manufacturer.

The waste oils generated from the servicing of the vehicles is collected and stored in underground waste oil storage tanks at the various locations. The tank sizes range from 500-2,000 gallons depending on the size of the service area. The waste oils are then hauled away by scavengers. Information on the fees paid for the disposal services or the quantities of waste oils involved were not available.

SIC MAJOR GROUP 55 - Automotive Dealers and Gasoline Service Stations

Five auto dealers were contacted. They had a combined total sales of 4,000 cars per year. Estimated purchases, totaling 11,400 gallons per year of multi-viscosity SAE10W-30 oil were made in 1973.

Waste oils are collected at all dealers, however no information on quantities was available. Three of the dealers pay a flat rate (approximately $9.00) every two months to have the waste oils hauled away. The other two dealers do not pay any fee; the oil is just picked up.

One of the newer auto dealers has an oil-water separator unit on the main discharge to the city sewer; the oil recovered is dumped into the same tank with the drain oils and collected. Outside run-off does not enter into this system.

SIC MAJOR GROUP 12 - Bituminous Coal and Lignite Mining

The company contacted purchased 960,000 gallons of lube oils in 1972. Most of this is used for trucks and other diesel engines. Some oil is used with additional fuel oil to spray coal in coal cars in cold weather; less than 20,000 gallons per year is used for this purpose. Some waste lube oils are used as fuel; however, most is collected by scavengers. The company pays 2¢ per gallon to have it hauled away.

Any fuel oils spilled are impounded, collected, and returned to storage tanks.

No. 2 oil is used as a frothing agent in those plants which have treatment facilities. This oil, along with coal particles, is returned to a coal pile. A total of 20,000 gallons per year for all plants is used for frothing.

SIC MAJOR GROUP 15 - Building Construction/General Contractors and Operative Builders

The company owns 100-150 trucks throughout the U. S., all serviced at service stations. They claim no waste oils are generated from equipment (all electric) or construction operations. The company is involved mostly in construction of commercial buildings.

SIC MAJOR GROUP 73 - Business Services

This maintenance and repair company owns three cranes serviced by the factory; 10 leased trucks, serviced under contract; and approximately 30 vans and pick-up trucks which are serviced at local stations.

Approximately 30 gallons per year of cutting oils are purchased which go out in the cutting chips. An estimated 350 gallons per year of waste oils generated from various jobs are taken to the town dump for disposal.

SIC MAJOR GROUP 28 - Chemicals and Allied Products

A single large chemical plant reported the following for their oil usage and disposal. For the year 1973, they purchased 1.2 million gallons of process oils. Of this 500,000 gallons were directly consumed in their products, 10,000 gallons were disposed of by incineration, 600,000 gallons went to landfill, and 75,000 gallons went to the treatment ditch. Purchases of lube oils for the same year totaled 620,000 gallons, 12,000 gallons of which were disposed of by incineration, with an additional 50,000 going to the treatment ditch.

From the treatment ditch, approximately 62,000 gallons per year is discharged into a river with other wastewater streams. The total wastewater discharge rate is 80,000 gallons per minute. The remaining 63,000 gallons, recovered as sludges and contaminated oil from the treatment ditch, are hauled to a landfill site. The company is studying means to recover oil usable as fuel.

SIC MAJOR GROUP 48 - Communication

Information was supplied for two typical plants manufacturing component parts for cummunication equipment.

Plant A manufactures small electronic parts. They purchase only 5-10 gallons per month for stationery machine lubrication. It is used for lubrication of bearings, electric motors, etc. All vehicles are leased and serviced under contract. The only waste oil that is generated is from the crankcase draining of two diesel powered generators. The oil is changed once per year and disposed of in the trash.

Plant B manufactures cable and various types of wire. The reported purchases of oils are as follows:

1. Vehicular crankcase oil for gasoline and diesel engines - 360 gallons per month.
2. Oil for stationary machine lubrication - 2,000 gallons per month.

3. Emulsified oils - 3,000 gallons per month.
4. Other metal working oils - 400 gallons per month.
5. Insulation oils - 800 gallons per month.
6. Hydraulic oils - 3,800 gallons per month.
7. Process oils - 5,000 gallons per month.

Plant B reclaims approximately 13,000 gallons per year of their stationary machine, metal working, and hydraulic oils through an outside re-refiner. The balance of the waste oils are disposed of via a local scavenger. A fee of $240 per month is paid for this disposal service.

SIC MAJOR GROUP 16 - Construction Other than Building Construction General Construction

On one major construction site, the company owns and services 22 large diesel driven rigs (cranes, loaders, crawlers, etc.) and 21 pickup type trucks. It also rents 35 larger trucks and vans. The maintenance shop services two vehicles per day. All waste oils that are recoverable are dumped into one of two 1,000 gallon storage tanks. Approximately 8,500 gallons per year of waste oil is hauled away at a cost of 3.5¢ per gallon. Form oils soak into wooden forms and go out with the scrap wood; 10,578 gallons of form oil has been used.

SIC MAJOR GROUP 58 - Eating and Drinking Places

The Company contacted has well over 500 restaurants throughout the U. S. Waste oils generated from the restaurants are beef and vegetable fats and oils, calculated to total 7,488,000 pounds per year. It is collected at each location by local tallow services which pay 1-1 1/2¢ per pound.

All company cars (over 100) are serviced at local service stations or under contract agreement with a leasing company.

SIC MAJOR GROUP 82 - Educational Services

All waste oils from the university's vehicles (SAE 10W-30), power equipment, and physical plant operations are collected and stored in 55 gallon drums. It is later blended into No. 6 fuel oil and burned in the main boilers. An estimated 100 gallons per month is disposed of in this manner.

SIC MAJOR GROUP 49 - Electric, Gas, and Sanitary Services

The power company interviewed has more than ten generating stations and many hundreds of electrical substations. No serious spillage problems from fuel oil tankage has occurred. The following discussion is, therefore, limited to other major types of oil used - for transformers, circuit breakers, and turbines. Little cable oil is used by this company.

Most generating stations and some substations have a waste oil tank with a capacity of about 10,000 gallons. Some waste oil is sprayed onto coal piles, and some used as road oil, but most is picked up by a collector. Some waste oil used to be applied as weed killer, but this is no longer practiced. No central data was available on oil purchases, or on waste oil collected. As will be discussed, considerable internal recycle (purification) occurs.

Transformer Oils

Direct purchases of transformer oils is very small, since most is bought with the transformer and used for its life. Purchases are generally limited to spillage makeup.

Transformers contain 2 gallons to 31,000 gallons, depending on size. Small transformers are shipped full; while, for large transformers, the oil is shipped separately and filled onsite. Transformer oil undergoes tests for dielectric strength before putting it into service. The oil is treated by means of portable vacuum equipment, primarily for drying. Testing of the full transformers is also done routinely to detect problems, including oil degradation. When oil problems are detected, the oil may be processed by use of vacuum equipment. Fuller's earth is used only when sludge is present. Transformers may be used for 40 years or more, in progressively less severe service, before discard. Upon discard, oil may be sold to special reprocessing companies, dumped to the waste oil storage tank, or left in the transformer. In the growing power industry, discard has been infrequent.

PCB oils are used for indoor transformers because of their fire resistance. These are handled as a hazardous material in sealed units. PCB's are disposed of by returning them to the PCB manufacturer.

Circuit Breaker Oils

Oil similar to transformer oil is used in circuit breakers for 69 kilovolt service or lower. The oil becomes contaminated by arc products, e.g. gases, such as methane and ethylene, carbon, and water. The useful life of this oil may be four years or more depending on the frequency of operation, which is monitored. Degraded oil is purified in mobile filter presses, or is taken out dirty to central cleaning facilities, and replaced with cleaned oil. Dielectric strength measurements are used to check the oil, which is discarded when it finally cannot be used. About 50,000 to 150,000 gallons per year are purchased.

Turbine Oils

Turbine oils are generally circulated through cloth filters to remove particles and centrifuged to remove water. The generating plants maintain storage facilities for both clean and dirty turbine oils. During turbine servicing, every two or three years, oil is removed to a tank and then returned. Makeup is required on older units, so that typical plants may purchase 100-1000 gallons per month of turbine oil. However, makeup for new units is negligible, as little as 12 gallons per 1000 service hours.

Older plants have oil/water separators and/or oil skimmers on the wastewater pond. Oil is first separated and recovered from a turbine room sump. Water is pumped to the wastewater facility. Little difficulty is encountered meeting 10 ppm oil and grease limits.

SIC MAJOR GROUP 36 - Electrical and Electronic Machinery, Equipment, and Supplies

Plant A - Approximately 200-300 gallons per year of waste oils were generated in-plant from the servicing of vehicles or industrial equipment, and from stationary machine lubrication and cutting oils. The waste oils are stored in 55 gallon drums and hauled away by a local disposal service.

Plant B - Waste oils generated in-plant, as described above, are segregated and the less contaminated oils are blended into the fuel supply. The remainder of the waste oils are hauled away.

SIC MAJOR GROUP 91 - Executive, Legislative and General Government

The information for a government service was collected from several of the agencies as no central source of data was available.

The highway department owns and services over 1,000 cars, trucks, and other pieces of equipment. It purchased 25,500 gallons of SAE 10W-30 multi-viscosity oil in 1973 for its service areas. Each service area disposes of its own waste oil by a local collector picking it up. There is relatively little shop oils or hydraulic oils handled. There was no central source of information on names or costs of disposal for the individual service areas.

The central motor pool services over 1,000 cars used by various agencies. An estimated 4,000 gallons per year of lube oil is purchased and used at the central maintenance shop. No records of the waste oil quantities have been kept as there is no cost involved. The waste oil is stored in a 500 gallon underground tank and is collected by a local waste oil collector.

Another agency estimates they generate 1,100 gallons per year of waste oils from vehicles and equipment. The waste oil is hauled away by a service at no cost to the agency.

The police department services its own vehicles (over 1,000) at four different locations. An estimated 11,000 gallons per year of waste oil is generated, and hauled away at each of the four locations by collection services.

The buildings department estimates generation of 250 gallons per year of waste oil. This comes from maintenance shops, air-conditioning units, and power equipment. It is blended into the No. 6 fuel oil tank and burned in the boilers.

SIC MAJOR GROUP 34 - Fabricated Metal Products, Except Machinery & Transportation Equipment

The following information came from one plant with approximately 1,000 employees.

Lube Oils Purchased For High Speed Production Equipment	Yearly Usage, Gal.	% Waste oil Generated	Primary Contaminant or Residue
A	2640	0	-
B	106	0	-
C	383	34	Sludge
D	990	20	Sludge
E	5480	81	Sludge (iron, tin, NH_4Cl, $ZnCl_2$)
F	165	40	Sludge (metal, heavy grease)
G	165	0	-
H	924	71	Sludge
I	1096	60	Sludge
Lube Oils Purchased For Lift Trucks			
Motor Oil	1095	30	Sludge
Trans. Fluid	218	30	Sludge
Miscellaneous Oils			
Gear Lube	217	0	Sludge
Cylinder Oil	106	0	Sludge
Other Oil	277	24	Varnish
	13862		

On various occasions the plant has tried oil reclaimed from these wastes. In each instance the trials gave unsatisfactory results. The practice now is to have the accumulated waste oils hauled away by an outside concern monthly (averaging 550 gallons per month). The overall cost for such collection and disposal averages 27¢ per gallon.

This is generally typical of the company's other manufacturing locations.

At a few of the other locations recent practice has been to add a major portion of these wastes to the No. 6 oil used for space-heating boilers. The sludge is not efficiently separated from the remainder of the waste oil; the "supernatant" liquid is merely "poured off" and added to the fuel oil, with only the remaining sludge hauled away by the scavenger. Such use of a portion of the waste oil for fuel is limited to the few plants equipped with boilers of the type that can handle such wastes without causing an air pollution problem due to the inorganic contaminants in the wastes.

SIC MAJOR GROUP 09 - Fishing, Hunting and Trapping

A fisherman's cooperative that services approximately 50 fishing vessels sells 36,000 gallons per year of engine crankcase oil. Sales of other oils are small in quantity (e.g. gear oils, hydraulic oil, etc.).

Crankcase oils are usually changed every 200 operating hours or every one to two weeks. The waste oils (approximately 10-20 gallons per vessel) are drained into old 5 gallon containers, which the crankcase oil is purchased in, and disposed of at sea or in trash receptacles at dock side.

SIC MAJOR GROUP 20 - Food and Kindred Products

A multi-plant meat processing operation was investigated. The operation included four types of plants: slaughter, integrated (slaughter plus processing), pure processing, and distribution. About 60lbs. of offal (blood, trimmings, bone, intestines, etc.) are recovered per animal and sold for various purposes, including edible and inedible tallows, animal feed, etc. About the only loss occurs when emulsified oils escape primary water clarifiers.

Wastewater discharge to municipal plants contain 100-300 ppm hexane solubles (oil + non-oil), attainable in normal clarifiers. Point source discharge requires further treatment, usually aerobic and/or anaerobic digestion to reduce hexane solubles to 5-10 ppm. Most plants discharge to municipal treatment, but some major plants are point sources.

Lower oil levels are sometimes achieved by polyelectrolyte addition and air flotation. Oil recovered from any clarifier operation is processed for use in soaps, commanding prices of 3-15¢/lb., depending upon quality. About 1% of the meat processed is recovered and sold as oils and fats. Clarifier sludges,containing 4-5% solids,are usually landfilled.

Total losses of oil and fat to wastewater and sludges may be on the order of 0.2-0.5% of the meat processed.

SIC MAJOR GROUP 54 - Food Stores

The following represents information on waste oil generation and disposal practices for all processing, distribution, and sales activities. Approximately 4,000 gallons per month of lubricating, hydraulic, and refrigeration oils are purchased. Waste oils are disposed of:

a) by burning in plant boilers (approximately 100 gallons per month),

b) road oiling or weed control at plant sites (approximately 700 gallons per month),

c) collection and removal via a local scavenger (500 gallons per month).

The balance of the oils are consumed in their particular use, lost due to leakage, or are unaccounted for.

SIC MAJOR GROUP 25 - Furniture and Fixtures

The company contacted manufactures wooden furniture and fixtures. The number of wood working machines in one typical plant averages about 500, with 700 to 750 employees. There are 18 tractor-trailers (diesel), 7 trucks, 3 cars, and 3 fork lifts, all of which are serviced at the plant.

Purchases of oil in 1973, for the one plant, totalled over 10,000 gallons of crankcase oil for vehicles and lubrication oils for stationary machines, with an additional 20,000 pounds of grease purchased for lubrication of wood working machinery.

All waste oils and greases are collected in-plant and stored in 55 gallon drums. The waste oil is then disposed of at a municipal dump or given away to farmers for lubrication of farm machinery.

Waste oils were disposed of, in the past, by using them for road oiling. However, this practice has been discontinued.

SIC MAJOR GROUP 53 - General Merchandise Stores

The company contacted owns and operates over 100 general merchandise retail stores. Approximately 25% of all the stores have an automotive service center. This is where the bulk of the company's waste oils are generated.

In a survey of 15 representative service centers, an estimated average of 200 gallons per month per location of waste oils are generated from crankcase drainings. These oils are disposed of at all locations via local waste oil collectors. Generally the only other source of waste oils in large quantities is from the company's fleet of vans and cars. These vehicles are usually serviced at their own automotive service centers, or at local service stations. All other vehicles or transportation equipment are leased and serviced under contract.

Most buildings, offices, and warehouses are heated electrically or by natural gas. Little or no fuel oil is handled. Any waste oils that are generated from the maintenance of these buildings would be small in quantity and disposed of in the trash.

The company does sell some automotive oils, less than 10% of which are sold in the service centers. They are generally purchased over-the-counter and used by "do-it-yourselfers" who service their own cars.

SIC MAJOR GROUP 80 - Health Services

The four vehicles owned by the hospital contacted are serviced at local service stations. An estimated 200 gallons per year of waste oils are generated from generators, compressors, and shop oils. It is collected by scavengers. However, no formal records are kept on quantities and there is no fee paid for the service.

SIC MAJOR GROUP 70 - Hotels, Rooming Houses, Camps and Other Lodging Places

The main office of this hotel chain leases more than 100 cars, all serviced under contract. One typical hotel generates waste oil from one car, which is serviced at a local station, lawn mowers, and a central chilling unit (serviced under contract). Vegetable oils from the kitchen are hauled away by a scavenger.

SIC MAJOR GROUP 63 - Insurance

The company has 200 cars across the U. S. which are serviced in local service stations. All equipment in the office buildings are serviced under contract, e.g. elevators, heating and air-conditioning units and transformers. They claim to generate no waste oils from any operation or maintenance they conduct.

SIC MAJOR GROUP 31 - Leather and Leather Products

The company contacted purchased approximately 1,800 gallons of various lubrication and hydraulic oils in 1972. They were used for servicing company vehicles, lubrication of stationary machinery, and hydraulic systems.

Twenty-five gallons per month of hydraulic oil is recycled using a filtration process, and the remaining quantity of waste oil is hauled away under contract by a local disposal company.

SIC MAJOR GROUP 41 - Local & Surburban Transit and Inter-urban Highway Passenger Transportation

One bus company that was contacted reported that their buses, either diesel or turbine, are serviced at various company centers throughout the United States. At all locations, waste oils from crankcase drainings, transmission fluids, etc. are collected and stored in underground storage tanks. It is then pumped out and hauled away by local scavengers. The quantities of waste oil and the fee or price paid for the disposal service was not available.

SIC MAJOR GROUP 24 - Lumber and Wood Products, Except Furniture

No central records were available. One large mill, greater than 500 tons per day, purchased the following for one year:

1. Mill lube oils, including paper machines, pumps, turbines and all lubricated systems - 308 drums (55 gal.) = 16,940 gallons.
2. Hydraulic oil - 15-20 drums = about 1000 gallons for hydraulic systems and elevators throughout plant.
3. Greases - 14,000 lbs.
4. Mobile equipment lube oil, including compressors- 133 drums = 7315 gallons.
5. Other lubricants, including vacuum oils, insulating oils, cutting oils, and gear compounds - small quantities.

Paper machine lube oil is filtered and centrifuged as necessary (water contamination makes oil milky), with some oil added as makeup. The capacity of a single machine is about 500 to 1000 gallons, which is replaced about once per year. A 2000 gallon waste oil tank is available. The waste oil may be blended with No. 6 fuel oil or removed by a collector. Water removed by the centrifuge goes to wastewater. Used oil from mobile equipment lubrication is drummed and collected, amounting to about 3000 gallons per year. However, some bulldozers are drained in the field over a bed of chips and bark.

Leakage from fuel oil tanks to a surrounding water filled berm is a problem, especially because the No. 6 oil density is close to and sometimes exceeds that of water. This leakage and oil from other systems do find their way into the wastewater treatment system, where some oil is skimmed, and finally to a large aerated holding pond, which discharges to a river.

Tall oil lost during pulping is also discharged into the wastewater system. The amount of tall oil lost varies with the type of wood processed and with the facilities available for recovery. Most western mills produce little tall oil. No information was available on the amount of oil contained in the wastewater effluent. The holding pond is covered by an oil containing scum which gradually degrades, or is blown away.

SIC MAJOR GROUP 35 - Machinery, Except Electrical

The machine manufacturing company that was contacted purchases the following types and quantities of oil per month:

1. Crankcase oils used for vehicular gasoline and diesel engines - less than 100 gallons per month
2. Oil for stationary machine lubrication - approximately 3,000 gallons per month
3. Soluble and emulsified oils, cutting oils - approximately 3,000 gallons per month
4. Other types of metal working oils - approximately 5,000 gallons per month
5. Hydraulic oils - approximately 5,000 gallons per month

These oils are dispensed from a central oil house to the manufacturing operations in 70 gallon containers which have hand pumps. After their specific use, the waste oils are caught in drip pans or sump systems on the metal working machinery and returned to the oil house in 500 or 250 gallon tank carts. Little spillage or leakage occurs in the handling of these oils.

Some of the cutting oils become contaminated with a red dye, used to mark metals for cutting. Others contain metal cutting chips, but most shavings and metal chips are recovered separately and contain virtually none of the cutting oils.

Almost all waste oils are disposed of through a waste oil collector. None are used as fuel. The waste oils are stored in either 55 gallon drums or larger storage tanks. An estimated 800,000 gallons per year of oily wastes are hauled away at a fee of 5-10 cents per gallon.

There is a small quatity of hydraulic oil being recycled, approximately 30 gallons per day. This process involves filtration and dehydration. However, no large scale recycling of waste oils is presently being practiced.

SIC MAJOR GROUP 38 - Measuring, Analyzing and Controlling Instruments; Photographic, Medical and Optical Goods; Watches and Clocks

A typical manufacturing operation (1 of 2 locations) has approximately 25 vehicles which are serviced in the maintenance shop. The drain oil is dumped into a waste oil storage tank. Together with hydraulic oils, gear oils, coolant and water soluble cutting oils, an estimated 72,000 gallons per year of oily wastes are hauled away by a local waste oil collection service. Of this, 40% is water from the cutting oils. An unreported fee per gallon is paid for the disposal service.

SIC MAJOR GROUP 10 - Metal Mining

The mining company contacted supplied the following information for one of their typical open pit mines. It's production rate is 50,000 tons per day of ore with an over-burden of 200,000 tons per day.

The oils purchased for this operation during 1973 were:

111,000 gallons	SAE 30	Crankcase oil
72,000 gallons	SAE 20	Crankcase oil
41,000 gallons	SAE 10	Hydraulic oil
9,000 gallons		Transmission fluid
233,000 gallons total		

The mobile equipment used in the mining operations are:

	Quantity
150 ton trucks	12
100 ton trucks	119
85 ton trucks	5
7.5 to 20 ton fork lift trucks	10
Bull dozers -D-8	29
Front-end loaders	
10 yd.	7
6 yd.	2
2 yd.	3
Electric shovels	8
Road Graders	9
Pickup trucks	65
Service truck 1-1/2 - 5 ton	40
Fuel trucks	3
Large low bogs	2
Water trucks 10-12 ton	8

Oil used for crusher lubrication in 1973 totalled 46,000 gallons. Oil purchased for miscellaneous usage in 1973 totalled 2,100 gallons.

All waste oils, resulting from maintenance of equipment, during the winter months are dumped with the discarded overburden. During the summer, about 15% of the waste oil is used for dust control on mine roads. The company claims that none of the waste oils get washed out of the mine or carried away.

Two alternative methods for disposal of waste oils are being considered at this time.

1. Re-refining on a toll basis.
2. Use with ammonium nitrate for blasting (new oil is used presently).

SIC MAJOR GROUP 14 - Mining and Quarrying of Non-Metallic Minerals, Except Fuels

A multi-plant mining and quarrying operation reported purchasing over 100,000 gallons of lubricating oil and over 150,000 pounds of lubricating grease in 1973. These were used for the servicing of company vehicles and equipment, shown below, which required an oil change on the average of 8 times per year.

Haul Wagons	44
Cranes	54
Air Compressors	12
Drills	9
Graders & Scrapers	9
Front End Loaders	38
Locomotives	1
Bulldozers & Tractors	13
Tugboats	11
Lift Trucks	27
Welders	24
Mixer Trucks	162
Tractor Trailers	2
Dump Trucks	2
Pick-up Trucks	37
Flat-beds	3
Dredges	5

All waste oils are stored and hauled away by a local scavenger at each of 15 locations. Approximately 4,000 gallons per month of waste oil, in total, is disposed of in this manner. No fee is involved for the disposal service.

SIC MAJOR GROUP 39 - Miscellaneous Manufacturing Industries

The main plant of the manufacturing operation contacted has six company trucks which are serviced at local service stations. All other waste oils from the plant are collected and stored in 55 gallon drums; approximately 650 gallons of water soluble cutting oils and 550 gallons per year of hydraulic oil are hauled away by a waste oil collector for 1-2¢/gallon paid to the collector.

SIC MAJOR GROUP 76 - Miscellaneous Repair Services

Company claims to generate zero waste oils. Vehicles are leased and serviced under contract; construction equipment that they lease to contractors generates zero waste oil (equipment has sealed bearings or grease fittings).

SIC MAJOR GROUP 89 - Miscellaneous Services

The institution contacted leases 5 cars and 17 trucks; all are serviced under contract. Approximately 250 gallons per year of waste oil is generated from the machine shop, maintenance of compressors, or repair of hydraulic systems. This includes all laboratory and office facilities. It is disposed of via a scavenger service.

SIC MAJOR GROUP 78 - Motion Pictures

Claimed to generate zero waste oils.

SIC MAJOR GROUP 42 - Motor Freight Transportation & Warehousing

The company contacted owns and services 260 Detroit Diesel tractors. Twelve thousand gallons per year of crankcase lubrication oil is purchased from Mobil.

They change oil every 15,000 miles. The crankcase of each engine holds 11 gallons of SAE 10W-30 oil. All drain oils are hauled away by a local waste oil service, however, no information on quantity or costs were available.

The garage where the tractors are serviced uses approximately 1,000 gallons per year of automotive parts cleaner. This is dumped into the drain oil storage tank and hauled away with the waste lubricating oil.

SIC MAJOR GROUP 84 - Museums, Art Galleries, Botanical & Zoological Gardens

Three facilities were contacted.

Zoo -- There was no information available on the amounts of oil purchased or their specifications. They service 20 trucks (gas and diesel) and 50 pieces of power equipment. They estimate 350 gallons per year of waste oils are generated from the vehicles and disposed of at the zoo's dump. Little or no other oils are used at the zoo.

Botanical Garden -- They purchase 600 gallons per year of SAE 30 oil and 30 gallons per year of hydraulic oil. Approximately 30 vehicles are serviced. The waste oils are stored in drums and hauled away by a waste oil collector. No fee is paid for the service.

Museum -- Five vehicles which are owned are serviced at a local station. The little waste oils generated from the building go out in the trash.

SIC MAJOR GROUP 72 - Personal Services

A laundry service operates and services 800 vehicles at one location. They purchase SAE 30 crankcase oil in bulk. However, no information on quantity was available. All waste oils are stored in an underground tank. Approximately 2,000 gallons of waste oil is collected every 2-3 months by a waste oil collector. A fee of 1¢ per gallon is paid to the collector.

SIC MAJOR GROUP 29 - Petroleum Refining, and Related Industries

Discussions with this company covered refining, marketing, production, and marine losses.

Refining

Oil losses vary widely from refinery to refinery, but careful operation may result in the following:

1. Evaporative losses as hydrocarbons to the atmosphere from tanks, flanges, etc. - 0.3% of total throughput.

2. Flare losses via CO_2 and H_2O - 0.1% of total throughput.

3. Other losses via liquids and solids (spills and wastewater; caustic, acid, biological sludges; tank bottoms; spent clay and catalyst; offspec polymer; rags and trash) - 0.1%.

Total losses in some refineries may be 1% or so, versus 0.5% total above.

Potentially recoverable losses (item 3. above) is disposed of in a variety of ways, for example:

- tank dewatering-to wastewater
- lubes, greases, hydraulic oils, cutting oils from vehicles, compressors, turbines, diesels, gas engines, and central lube systems-picked up by vacuum trucks and deposited in slop tanks, or drained into wastewater system.
- tank cleanings and oily dirt from spills - internally or to outside contractors for incineration or landfill
- barometric condensers - on way out, but oily water from those remaining to wastewater
- flanges leaking liquids - oil picked up by vacuum trucks and deposited in slop tanks, by absorbents and to landfill, or lost by evaporation
- tank spills - contained in fire walls and pumped to slop tanks
- caustic sludges - sold to companies who recover cresylics and other chemicals, and paper companies
- API separator sludges - some to outside contractors and some to "landforming" (oxidation in layers 4 to 6 inches deep using disc cultivators)
- slop tank liquids - to special distillation for recovery of crude products
- other sludges and solids - to outside contractors, landforming, and fixation (outside contractors add materials which cause reactions resulting in inert fill material)
- biological sludges - generally to outside contractors, thence to landfill
- oil in wastewater systems - about 85-90% removal to 15 ppm or less (oil recovered to slop tanks)

The net result is considerable internal recycle with a very small percentage actually lost. However, even this represents relatively large volumes; for example, 0.1% loss is equivalent to almost 300 million gallons per year nationwide.

Marketing

Oil losses in marketing operations take place at numerous terminals and bulk plants. The terminals which service pipelines, barges, and tankers all have oil/water separators, but not all bulk plants have such facilities. Oil losses include evaporative and spill losses; pipeline interface and offspec oils; transfer losses; and tank, truck, barge, railroad car, and tanker cleaning residues; tank dewatering losses; and rain water drainage losses. Some of these oils are collected by scavengers (e.g. oils skimmed from separators, tank cleaning residues, oils gathered from vehicle draining, and oils gathered from repair shops); some are blended back to products (e.g. Bunker oils recovered from loading area drains, interface oils, and clean spill oils). Slop tanks in terminals are often a depository for oils collected through spill cooperatives.

Production

Crude oil production almost always leads to oil/water mixtures. Modern facilities use heater-treaters to produce pipeline quality oil. These are baffled tanks where heat and chemicals are used to break oil/water emulsions. The water is subsequently treated by a variety of methods, including oil/water separators, flotation, and sand filters. These normally reduce oil content to 60-200 ppm, before discharge to wells, waterways, the Gulf, etc. depending upon location. Water quantities are small compared to refinery water systems, and total oil losses are probably on the order of 0.01%, with spill losses being the same order of magnitude.

Marine

Refineries and terminals receive oil contaminated waters from tanker washing, and ballast and bilge water. Most of this water is handled at Gulf Coast terminals from U. S. flag product carriers of less than 75,000 tons.

Product carriers require relatively little cleaning, perhaps every 2-4 years. When cleaning is necessary, tanks are usually cleaned at sea and water brought to shore for discharge to holding tanks, though some water may be decanted at sea.

Bilge and ballast waters are also brought to shore, requiring tanks which may hold over 100,000 barrels (4,200,000 gallons), although some ballast changes may be made at sea.

Oil/water separation occurs in the receiving tank. Oil is transferred to slop tanks in refineries (the same tanks as previously discussed) for recovery. Water is further purified in separators and/or biox systems.

Increases in future crude demand will find considerable crude receipt at Gulf Coast refineries, requiring some changes in marine oil practices. Foreign flag tankers carrying black oil (crude) are generally cleaned only once in 5-10 years, but contaminated water has normally been discharged at sea.

SIC MAJOR GROUP 46 - Pipelines, Except Natural Gas

Common carrier of petroleum products and crude with a thruput for 1973 of over 200,000 barrels per day. Major types transported include premium gasoline, regular gasoline, #1 heating oil, #2 heating oil, kerosene, naphtha, JP-4 jet fuel and crude. Sources and disposition of waste oils are:

1. Oil recovery from terminals which have oil-water separators -- waste oil is returned to slop tank.
2. Oil resulting from tank cleaning -- hauled away by a contractor.
3. Contaminated water withdrawn periodically from tanks -- hauled away by a contractor.
4. Oil spills -- spills have been on the order of 1% of the total thruput. Recoverable portions of spills are recovered and returned to slop tanks, while in some cases a large amount evaporates (gasoline).
5. Virtually no loss of interface oils occur. They are small in quantity and are blended off gradually into suitable products.
6. Slop tank oils are blended gradually into suitable products.
7. Losses are being minimized by shutting down and replacing older lines, and by improved preventive measures against line breakage by outside contractors.

SIC MAJOR GROUP 33 - Primary Metal Industries

One large steel plant might purchase the following yearly quantities of oils and lubricants:

Absorbent oils	150,000 gal.
Maintenance and hydraulic oils	500,000 gal.
Motor oils	4,000 gal.
Rust preventative & slushing oils	200,000 gal.
Transmission fluids, gear oils & compounds	200,000 gal. + 400,000 lbs.
Rolling oils, including animal & vegetable fats and oils	2,500,000 lbs.
Open gear compounds	20,000 lbs.
Maintenance greases	250,000 lbs.

In addition, many plants purchase synthetic oils, and metal working compounds and oils (including those containing fats, sulfur and chlorine).

Absorbent oil, used for recovering light oils from coke ovens, is recycled but the makeup quantity leaves the steel plant with a heavy light oil fraction. Considerable recycle of cold rolling oils is practiced, with the quantity of recycle often the same order of magnitude as the purchased oil shown above. Some hydraulic oils and other used oils which can be isolated are reclaimed both within plants and by outside contractors. For example, transformer oil is sometimes recycled by filtering, dewatering, and "active earth" treatment. Reclaiming has expanded with current oil shortages.

Some waste oils and sludges are disposed of to contractors who landfill or burn them. For example, these include some acid and tar sludges from coke oven operations, waste soluble cutting oils, waste fuels, and other contaminated waste oils.

In general, waste oils which are diluted with water, from mills and other operations, are sluiced to sewers and thence central wastewater treatment facilities. Other waste oils are collected in large portable containers to be reclaimed for fuel or other uses.

Oil from the wastewater system is often skimmed and reclaimed for rolling oil or fuel use by cooking, acid treating, or other processing. Further treatment of wastewater by lime, aeration, and sedimentation yields waste solids containing some residual oil, which is concentrated to about 30% solids and disposed of by landfill.

Lagooning of sludges is being phased out. Sludges from rolling mills contain considerable iron and anywhere from traces of oil to 30% oil. Some plans are being made to incinerate certain sludges (i.e. to burn the oil off and vaporize water)before feeding to sinter plants.

Not all steel plants have adequate wastewater facilities with oil recovery, but these are gradually being updated to meet new standards.

SIC MAJOR GROUP 27 - Printing, Publishing, and Allied Industries

A fleet of over 100 company owned gasoline engine trucks are self serviced. Waste oil is collected in a 250 gallon tank and removed by a waste oil dealer who reprocesses the oil, probably to fuel use. Some additional diesel trucks are leased and serviced by the leasor, who also transfers waste oil to a collector.

About 200 gallons per month of oil find use in gearboxes, and in drip feed to a compressed air system for air cylinders. About 5 gallons per month of a viscous emulsified moly oil is used for chain conveyors. Oil is drained and recovered only upon failure of equipment. About 300-400 gallons per year is so recovered, put into drums, and transferred to a collector. Some oil is lost to rags which are used, with solvents, to clean presses and machinery. These are returned to a laundry.

Another source of oil in high speed letter press printing is the oil mist which leaves the presses and is recovered by a combination vacuum/centrifugal filtration system. This oil, which amounts to less than 0.1% of the ink used, is recycled to the ink (85% mineral oil/15% carbon black). Ink oils are eventually lost, of course, with the printed paper. Letter presses may use about 35-37 lbs. of ink per ton of newsprint; letter presses about 2/3 of this quantity.

SIC MAJOR GROUP 40 - Railroad Transportation

Purchases of lubrication oils and greases totalled 7,249,668 gallons in 1973. The major purchases, by type, are as follows:

Over 500,000 gallons diesel engine crankcase oil

Over 30,000 gallons SAE 10W-30 lubrication oil

Over 1,000,000 gallons non-additive journal oil

About 10,000 gallons SAE 90 gear grease

Over 50,000 gallons bearing grease

Over 200,000 gallons roller bearing grease

Over 10,000 gallons insulation oils

Over 50,000 pounds 'asphalt' gear grease

Over 200,000 pounds flange grease

Over 100,000 gallons reclaimed diesel crankcase oil

In 1973 over 600,000 gallons of car journal oil and over 160,000 gallons of diesel engine crankcase oils were reclaimed by outside waste oil re-refiners. Proper reclaiming has been a problem.

Waste oil reclaiming and disposal practices are:

1. Locomotive diesel engine crankcase oil - usually reclaimed and re-fortified with additives for reuse as diesel crankcase oil (by outside re-refiner).

2. Spilled or contaminated fuel oil - spillage from refueling operations (over 100 locations) is captured in fiberglass drip pans. It is generally sold to scrap dealers, but some is filtered and returned to storage for the original intended use. The latter is the recommended approach and is being promoted.

3. Mixed scrap oil from oil/water separators - mostly spilled fuel oil, sludges from tank

cleanings, or other waste oils that have not been segregated for re-refining. These are usually sold to scrap dealers. Attempts are being made to recover some by filtration or other methods.

Small quantities are being blended into No. 6 fuel oil and burned at two locations.

The following impurities were mentioned as present in waste oils:

1. Crankcase oil - soot, fuel oil, water, oxidation products.
2. Fuel oil - dirt and water.
3. Mixed scrap oil - dirt, water, detergents.

Detergents which contaminate waste oils were noted to increase difficulty in reclamation.

Detailed information by specific location was unobtainable.

SIC MAJOR GROUP 65 - Real Estate

The company contacted provides maintenance services for large office and residential buildings. Their policy, in brief, is to dispose of the small amount of waste oils generated to trash collection. Approximately 3 gallons per year is crankcase oil drained from a back-up diesel generator, and 10-15 gallons per year is lubrication oil from the turbine drive in the central air-conditioning system. All other systems are self-contained or are under a service-contract with the manufacturer (e.g. elevators, cooling towers, and transformers).

SIC MAJOR GROUP 30 - Rubber & Miscellaneous Plastics Products

The following purchases of oils were reported for the company's many plants throughout the United States:

1. Crankcase oil used for vehicular gasoline engines - 1,200 gallons per month.
2. Crankcase oil used for vehicular diesel engines - 1,125 gallons per month.

3. Oil for stationary machine lubrication - 620,000 gallons per month.

4. Soluble and emulsified oils - 6,200 gallons per month.

5. Other metal working oils - 1,000 gallons per month.

6. Insulation oils - 1,350 gallons per month.

7. Hydraulic oils - 33,750 gallons per month.

8. Oil used as a raw material in processing - 1,412,000 gallons per month.

The general waste oil disposal practice, for all plants, is to use industrial waste oils, excluding crankcase drainings and other badly contaminated oils, for fuel. An estimated 150,000 gallons per month, 90,000 gallons of which are a by-product from a chemical process, are disposed of in this manner. At one plant alone, 5,000-7,000 gallons per week of waste oils are filtered and added to the fuel supply.

Waste oils that are not used as fuel are collected in 55 gallon drums and hauled to landfill sites by commercial disposal services. The fee paid for this service is about 10 cents per gallon. These oils include crankcase drainings from material handlers, oils skimmed from API oil/water separators, and oils that cannot be segregated in-plant and become contaminated, preventing their use as a fuel. Crankcase, transmission, or other oils containing additives seem to cause plating problems in the plant boilers when used as fuels.

SIC MAJOR GROUP 32 - Stone, Clay, Glass and Concrete Products

Six typical plants of the company contacted reported purchases of lubricating, hydraulic, and process oils of over 40,000 gallons in 1973, for vehicles, mining equipment, etc. A breakdown on the types of oils and their specific applications was not available. All waste oils are collected, stored and, disposed of in one of three ways:

a) disposal via a local waste oil collector accounts for the bulk of the waste oils generated in the six plants.

b) burning of industrial waste oils in plant boilers (small quantity).

c) flushing down in-plant drains, where oil is later separated (oil/water separators in wastewater treatment system) and disposed of with the other oils being hauled away by a collector.

SIC MAJOR GROUP 21 - Tobacco Manufactures

The bulk of waste oils generated from tobacco processing activities are from transmissions, gear motors, and machine tool coolants. Their waste oil disposal and reclamation practices in 1972 were as follows:

- 5,000 gallons reclaimed
- 2,000 gallons given away
- 78,000 gallons hauled away by a commercial disposal company
- 600 gallons to landfill by commercial disposal service.

This totals 86,000 gallons of waste oils accounted for out of 90,000 gallons of lubricating, hydraulic, and cutting oils purchased in 1972.

The commercial disposal service previously charged $3.50 per barrel of waste oil and returned the barrel. Now it charges $8.25 per barrel and keeps the barrel. These new costs caused the company to look for new disposal methods, at long-life coolants and self-treating facilities.

As a result, the company policy for disposal of waste oils has changed since 1972. Now all waste oils are drained, collected, and given to a subsidiary for use as fuels, except if the oils are wet, very fouled, or volatile.

SIC MAJOR GROUP 45 - Transportation By Air

Waste oils are generated both at airports and central maintenance centers. Some typical airport examples are:

1. Aircraft sumping - 500 gallons per month turbine fuel scheduled and non-routine for maintenance purposes, for one airline at one airport.

2. Facilities and dispensing vehicle sumping - 300 gallons per month turbine fuel for one airline at one airport.

3. Ramp spills - seldom exceeds 35 gallons turbine fuel per spill. However, hydrant failure has, in one known instance, caused an approximate 2,000 gallon spill. No predictable average. Leaks, spills, failures of other fluids from aircraft and ground vehicles are insignificant until total accumulation is washed off by rain.

4. Loading facility spills - with dry type disconnects, do not expect monthly spills to exceed 20 gallons total turbine fuel. Accidents or carelessness have caused 200 gallon spills.

5. Gasoline - may have occasional small leaks which contribute to ramp pollution, but generally no problem.

6. Petroleum based lubricants (engine and transmission) - 500 gallons per month for one airline at one airport.

7. Heavy petroleum based greases - 160 lbs. per month for one airline at one airport.

8. Deicing fluids - usage varies drastically from year to year and from one location to another, but during one 24-hour period in a major northern airport, 100,000 gallons of fluid were used.

9. Synthetic lubricants - one airline at one airport might use up to 150 gallons per month. Total airline system might use 40,000-50,000 gallons yearly.

10. Aircraft exterior and ground support equipment washing and cleaning compounds - 25,500 gallons per year before dilution, or up to 250,000 gallons per year after dilution with water.

Recommended methods for handling fluid spills follows:

Type of Fluid	Disposition Method
Turbine Fuel & Petroleum Solvents	Large spills (over 50 square feet of wetted area) - Water flush to a safe collection area where the fuel may be mechanically separated from the water and picked up by refuse collector.
	Small spills (under 50 square feet of wetted area) - Pick up with filter clay or absorbents and burn or hold for refuse collector.
Gasoline	Large spills (over 50 square feet of wetted area) - Block the spill area from motorized traffic. Notify airport fire department. Water flush to safe collection area where the fluid may be mechanically separated from the water and picked up by refuse collector.
	Small spills (under 50 square feet of wetted area) - Pick up with filter clay or absorbents and remove to a safe area to burn or evaporate.
Petroleum & Synthetic Oil & Petroleum Hydraulic Fluids	Pick up with filter clay or other absorbent and burn or hold for refuse collector.

Type of Fluid	Disposition Method
Synthetic Hydraulic Fluids	Spills - pick up with filter clay or other absorbent and hold for refuse collector. Drained - store in 55 gallon drums. Laboratory tests will determine reusability: 1. Reusable: Filter and return to service. 2. Reclaimable: Send to manufacturer for credit on new fluid. 3. Non-reclaimable: Hold for pickup by refuse collector.
Chlorinated Solvents	Pick up with absorbents and remove to safe open air area for evaporation.
Toilet Germicides & Toilet Wastes	Pick up lavatory spills with scrub brush-equipped tractor vacuum unit with brushes in raised position. Following removal of waste, brush scrub and revacuum the area. Discharge the waste through triturator to sanitary sewer.
Deicers & Antifreeze (Ethylene Glycol based)	Flush to storm drain with large quantities of water to provide thorough dilution.

Contaminated fuels are sold for fuel value, for example, No. 2 fuel oil. Contaminants are minor, but may include aviation gasoline and microbial contamination, but little or no water. Other waste oils are generally picked up by a collector. However, as can be seen from the previous discussion, considerable oil and deicing fluids may enter airport wastewater systems, with proper disposal depending upon the adequacy of those system. Little firm data is available, but discussions with airport officials raise doubts as to the present effectiveness of airport wastewater treatment, usually controlled by independent authorities.

The central maintenance facility collects most waste oils from wastewater recovery and other sources in a waste oil tank (about 2000 gallons), but other waste oils from shops, the test cell, and ground equipment is collected in 55 gallon drums. A total of about 1000 gallons per month of oil-type fluids is picked up by a collector at a cost to the airline of $150. per month. About 400,000 gallons per day of wastewater effluent is injected into a high pressure deep well approved for that purpose.

SIC MAJOR GROUP 37 - Transportation Equipment

The metal fabricating company contacted has had an ongoing program of oily waste treatment and recovery for many years. During the past year they reclaimed 19 million gallons of oil. About 40% was used for lubrication and about 60% for fuel.

A low quality recovered oil is provided from one source to a public utility which uses it as fuel to generate power. Other plants use recovered oil for fuel in boilers, in forge furnaces, or reconstitute the oil themselves, or through an outside service, for manufacturing operations. They claim not to dispose of recoverable oil to waste.

A general description of the waste oil recovery process that is used in several plants follows:

An equalizing and holding tank is used as an in-plant collection system. The tank is divided into compartments to provide a semi-fill and draw procedure which equalizes the waste. They have a 16 to 24 hour residence time to provide filling and gravity separation of the oil. In some plants new corrugated plate separators have been installed in the raw waste line to remove the bulk of free oil and solids prior to the holding tanks.

Influent waters vary in oil content from 2,000 to 5,000 mg/l. About 90% of this oil separates by gravity and can be removed as "free oil." In some cases this oil can be reused as cutting oil without further processing. However, the major portion of this oil contains some emulsifier and water which forms an invert emulsion layer. The free oil is pumped to a lead lined evaporator where this emulsion is broken by heat, sulfuric acid, and occasionally de-emulsifying agents. After settling, a three phase separation occurs - oil, acid water, and a rag or scum interface layer.

The acid water is used for pH control of the raw waste or final effluent. The rag layer is recooked. The resulting oil is equivalent to No. 4 fuel oil. Some nine million gallons of this oil is recovered annually by the plants employing this type of waste oil treatment. The oil is utilized in general for fuel in boilers and forge furnaces.

The oily wastewater in the lower portion of the holding tank is pumped to a mix tank where, after polymer injection at the pump intake, alum is added in dosages of 25-50 mg/l.

The treated waste is fed by gravity to a dissolved air flotation cell where the floc formed is removed. The effluent overflows to a third mix tank where pH adjustments may be made to dispose of excess acid. The float or scum oil is pumped to a cooker and treated similarily to the free oil. The effluent water is run through a clarifier and discharged.

SIC MAJOR GROUP 47 - Transportation Services

The company contacted is a conglomerate of smaller trucking firms throughout the United States. One typical company owns and operates 110 diesel trucks.

They purchase 2,600 gallons of multi-viscosity SAE 10W-30 crankcase oil and 40 gallons of hydraulic oil per year. The trucks, which have either Detroit or Cummings diesel engines and have a crankcase capacity of approximately 10 gallons, are serviced every 15,000 miles. The drain oils are stored in a 550 gallon waste oil tank and hauled away every two months by a waste oil collector. They claim to pay 33¢ per gallon for this service. An estimated 1,800 gallons of waste oil per year is disposed of in this manner.

Engines and parts are cleaned by steam in a maintenance shop. The wastewater from the cleaning operations is washed down the city sewer. They could not estimate the amount of water or oil and grease content discharged as there is no wastewater pre-treatment involved.

SIC MAJOR GROUP 44 - Water Transportation

The company contacted owns and operates several turbine driven, containerized cargo ships.

Lubrication oil for the turbines (marine oil, non-detergent) is circulated through a 'Sharples' oil purifier, which removes water, dirt, and metal particles by filtration and centrifuging. The oil is then held in a sump and returned to the turbine as required. Approximately 1,700 gallons per turbine are recycled in this manner. Any other spilled or reclaimable oils from drips, etc, on board ship are returned or added to this system. Oils that are not reclaimable by this purification system (drain oils from back-up generators, air compressor oils, vent traps) are blended into Bunker tanks and burned in the boilers.

This amounts to approximately 15 gallons per year per vessel. Cutting oils from the shop are reused or are disposed of in cleaning rags that go out with the trash.

The bulk of waste oils generated from shore side operations would be from motor vehicles which are leased and serviced under contract. Disposal and reclamation practices for waste or spilled oils on board the vessels are as follows:

Oil Pollution

Effective July 1, 1974 all vessels will be subject to the "Clean Water Act" while in the continental boundaries and contingency zones of the United States. This area extends fifteen miles off shore and encompasses all waters therein.

There is no mathematical designation as to the amount of oil that constitutes pollution. The law states:

> DISCHARGE OF OIL PROHIBITED
>
> The Federal Water Pollution Control Act prohibits the discharge of oil or oily waste into or upon the navigable waters and contiguous zone of the United States if such discharge causes a film or sheen upon, or discoloration of, the surface of the water, or causes a sludge or emulsion beneath the surface of the water. Violators are subject to a penalty of $5,000.

It is the company's desire that all vessels will comply immediately without waiting until the effective date. The following practices will be instituted immediately:

Bilge Pumping

All vessels will pump bilges dry before entering the contingence zone. No bilges are to be pumped while in port.

In an emergency, or due to some unusual circumstances that requires any bilge pumping in U. S. ports, it will be discharged into a slop barge or to a holding tank aboard. Your vessel is permanently piped to take suction from bilges and discharge through the oily ballast system into any tank. The smallest fuel oil tank aboard should be used as the holding tank. It is not the intent that this holding procedure will be used routinely. Any time conditions require its use the home office is to be notified. When this tank is discharged the home office is again to be notified in order to be aware at all times of your bunker capacity.

It will be necessary to install an interrupting stop button adjacent to the filling stations to stop the appropriate bilge pump that is piped to discharge to the filling line. A separate directive will cover this installation.

Upon departure from U. S. Ports if the Watch Engineer desires to pump bilges he shall call the Bridge to ascertain that the vessel is outside the contingence zone and shall log the fact in the Engine Room Log.

If your vessel is equipped with automatic bilge pumps they shall be secured at all times the vessel is within the contingency zone.

Cargo Oil

If your vessel is fitted with cargo oil tanks, the U.S. Coast Guard Certification of these tanks is being withdrawn and the tanks henceforth will be classed dry cargo or ballast.

Bunkering

The new laws covering transfer of oil from dock to vessel or from vessel to vessel are very explicit as to the steps to be taken. It is not the intent to paraphase them at this time. The laws are contained in U. S. Coast Guard publication CG-257 titled "Rules and Regulations for Cargo and Miscellaneous Vessels", Subchapter 1 dated April 1, 1973.

Some of the interpretation follows:

Oil shall be taken under the supervision of "Person in Charge". This shall be the Chief Engineer.

1. Declaration of Inspection

   Attached are copies of the "Declaration of Inspection" based on 33 CFR 156.150 and 46

CFR 35.35-30. This check list is to be jointly checked off and signed by the receiver and deliverer who will be responsible for the areas each has checked. The person signing the "Declaration of Inspection" becomes the "person in charge" as defined by the law. This shall be the Chief Engineer. This certificate shall be held on board for thirty (30) days.

2. Containment of Vents, Overflows and Filling Lines

On vessels constructed prior to July 1, 1974 it will be acceptable by the U. S. Coast Guard when bunkering to have a bucket of at least five gallon capacity secured to each vent. While the law states they shall be eighteen inches high it has been clarified with the U. S. Coast Guard that paint buckets will suffice even though they do not meet the required height.

On filling stations and where the diameter of the vent does not make it practicable to use paint buckets it is suggested that thirty or fifty gallon barrels be adapted. While it is not required, the company suggests that all goosenecks from fuel tanks and a ship set of containment buckets be painted red and that the ship's set of buckets be used for no other purpose.

It is recognized that on some vessels the arrangement of the vents on deck are such that a containment bucket can not be affixed. When this condition is found, structural changes can be made prior to July 1, 1974.

3. Transfer Procedure Manual

Transfer Procedure Manuals for each class of vessels are being prepared and will be forwarded to your vessel. This manual shall be kept in the Engine Room log desk.

4. Required Personnel and Their Duties

Specific duties and required personnel are required during any transfer of oil, dock to vessel or vessel to vessel.

Chief Engineer - "Person in Charge" who shall fill out and sign the Declaration of Inspection.

Second Engineer - In Engine Room in charge of all manifolds.

One (1) Engine Department member at filling station to communicate with deliverer.

On Deck one (1) Officer and one (1) seaman to tend lines.

In addition to the five required personnel such other ship's personnel as may be deemed necessary by the "Person in Charge".

Placard

Your vessel is being furnished with two (2) decals with wording required by law to be affixed to a metal plate and permanently mounted. In the Engine Room, one shall be adjacent to the bilge and ballast pump control station and one at a convenient location on the Bridge.

Plugging Scuppers

Nothing in the above mentioned regulations relieves the requirement that all scuppers and deck drains be plugged.

Reporting Oil Spills or Pollution

In the event of any pollution while in port,the U. S. Coast Guard in the port you are in is to be immediately notified.

While the above touch upon pollution through fixed piping it should be borne in mind that anything emminating from the vessel that causes "a film or sheen or discoloration" is considered by law to be pollution from the vessel.

SIC MAJOR GROUP 50 - Wholesale Trade/Durable Goods

The company contacted leases 50 vehicles which are all serviced under contract. They claim to generate no waste oils from their buildings, maintenance,or other operations.

SIC MAJOR GROUP 51 - Wholesale Trade/Non-Durable Goods

The bulk of waste oil generation is from motor vehicle maintenance. Eight trucks (gas and diesel) are owned and serviced by the company. The waste oils are drained and stored in 55 gallon drums to be hauled away be a scavenger, at a fee of 2-3¢ per gallon.

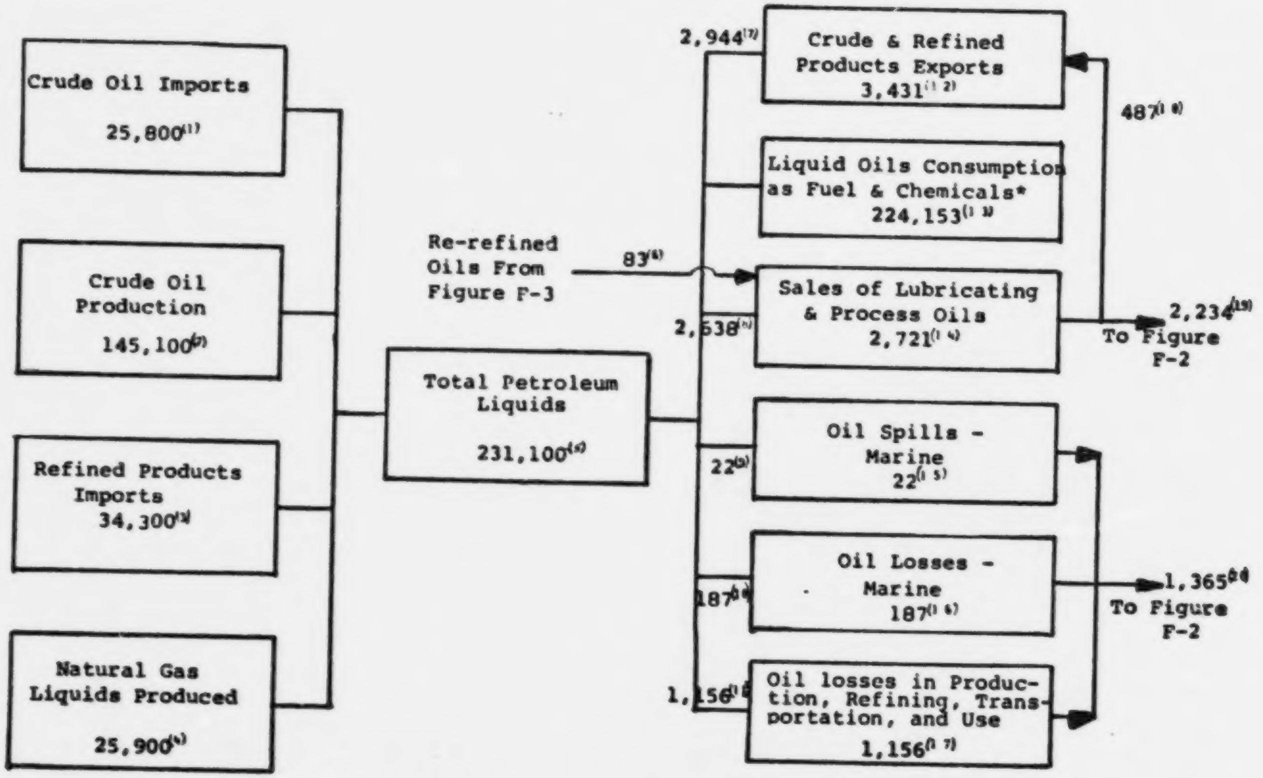
The company claimed to generate no other waste oils from maintenance or manufacturing operations.

APPENDIX F

WASTE OIL MATERIAL BALANCE METHODOLOGY

FIGURE F-1 U.S. CRUDE OIL DISTRIBUTION +

(Millions of Gallons Per Year)

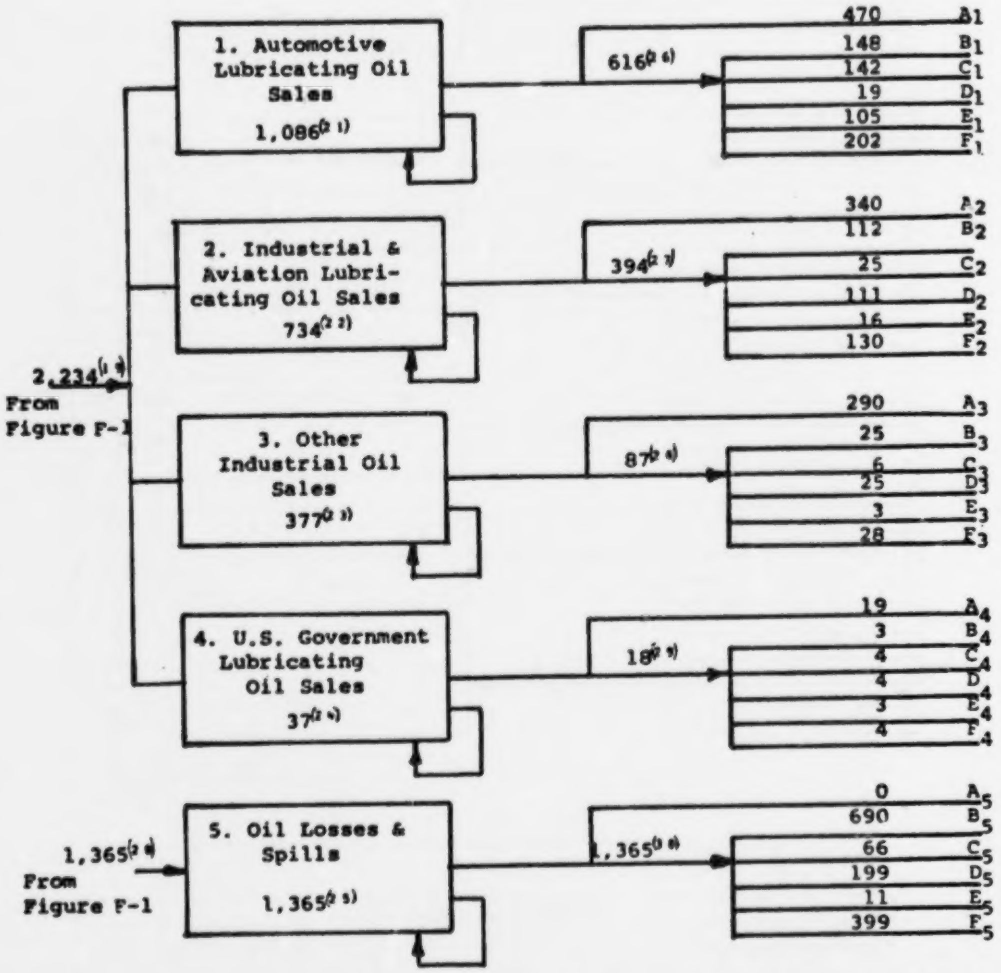

Crude Oil Imports
25,800[1]
Crude Oil Production
145,100[2]
Refined Products Imports
34,300[3]
Natural Gas Liquids Produced
25,900[4]
Total Petroleum Liquids
231,100[5]
Re-refined Oils From Figure F-3
83[6]
2,944[7]
2,538[8]
22[9]
187[10]
1,156[11]
Crude & Refined Products Exports
3,431[12]
Liquid Oils Consumption as Fuel & Chemicals*
224,153[13]
Sales of Lubricating & Process Oils
2,721[14]
Oil Spills - Marine
22[15]
Oil Losses - Marine
187[16]
Oil losses in Production, Refining, Transportation, and Use
1,156[17]
487[18]
2,234[19]
To Figure F-2
1,365[20]
To Figure F-2

* By difference

+ See Table F-1 for key to data sources

FIGURE F-2 WASTE OIL GENERATION *

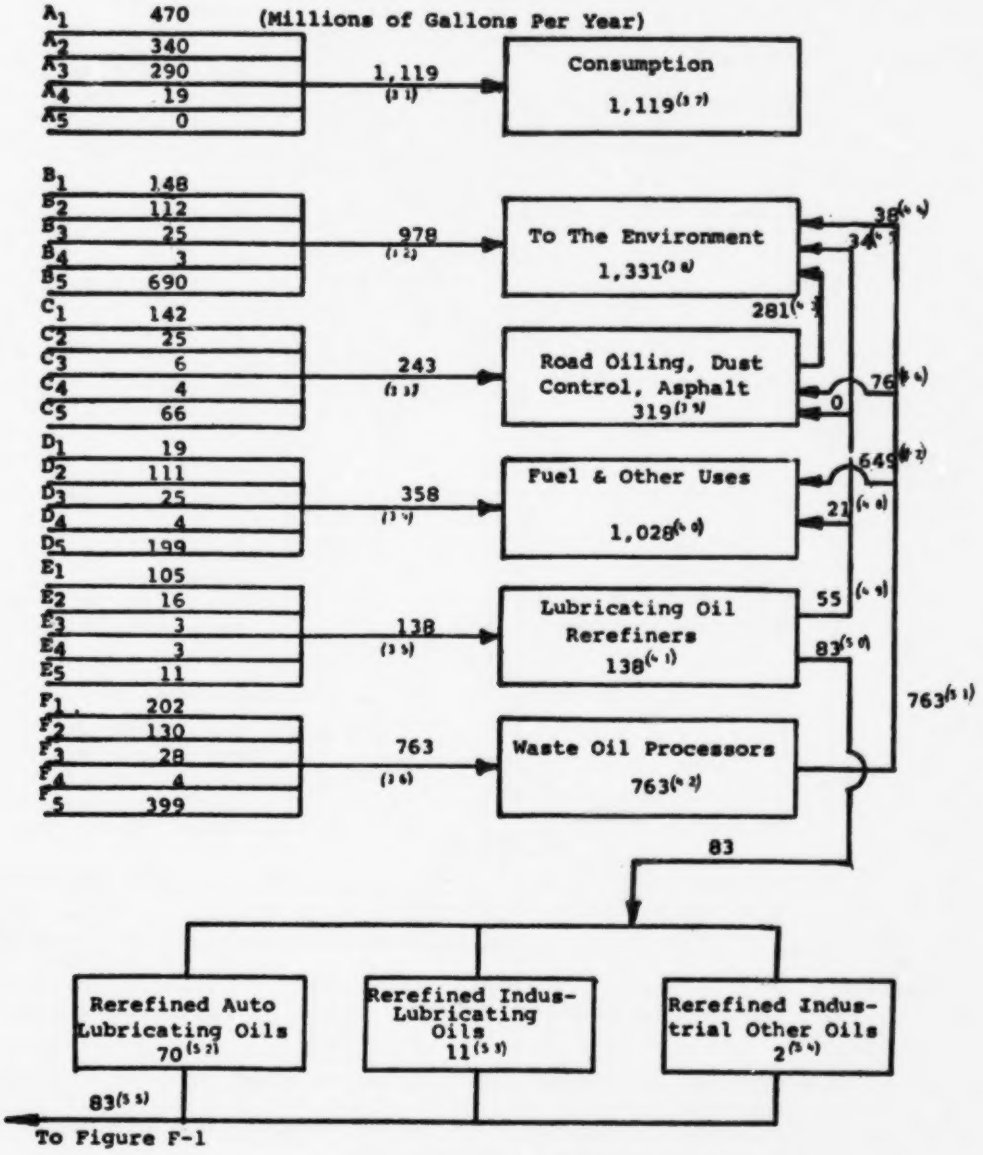
(Millions of Gallons Per Year)


1. Automotive Lubricating Oil Sales
1,086(21)
616(26)
470 A1
148 B1
142 C1
19 D1
105 E1
202 F1
2. Industrial & Aviation Lubricating Oil Sales
734(22)
394(27)
340 A2
112 B2
25 C2
111 D2
16 E2
130 F2
2,234(19)
From Figure F-1
3. Other Industrial Oil Sales
377(23)
87(28)
290 A3
25 B3
6 C3
25 D3
3 E3
28 F3
4. U.S. Government Lubricating Oil Sales
37(24)
18(29)
19 A4
3 B4
4 C4
4 D4
3 E4
4 F4
1,365(20)
From Figure F-1
5. Oil Losses & Spills
1,365(25)
1,365(30)
0 A5
690 B5
66 C5
199 D5
11 E5
399 F5

A = Consumed as lubricating oil, fuel or other use by the original purchaser/user.
B = Potentially discharged to the environment (land or water)
C = Used as road or dust control oils
D = Used as fuel or for other purposes
E = Sent to lubricating oil re-refiner
F = Sent to waste oil processor
* See Table F-1 for key to data sources

FIGURE F-3 WASTE OIL DISPOSAL *

(Millions of Gallons Per Year)



A_1 470
A_2 340
A_3 290
A_4 19
A_5 0
1,119 (31)
Consumption 1,119(37)
B_1 148
B_2 112
B_3 25
B_4 3
B_5 690
978 (32)
To The Environment 1,331(38)
38(44)
34(45)
281(43)
C_1 142
C_2 25
C_3 6
C_4 4
C_5 66
243 (33)
Road Oiling, Dust Control, Asphalt 319(39)
76(46)
0
D_1 19
D_2 111
D_3 25
D_4 4
D_5 199
358 (34)
Fuel & Other Uses 1,028(40)
649(47)
21(48)
E_1 105
E_2 16
E_3 3
E_4 3
E_5 11
138 (35)
Lubricating Oil Rerefiners 138(41)
55(49)
83(50)
763(51)
F_1 202
F_2 130
F_3 28
F_4 4
F_5 399
763 (36)
Waste Oil Processors 763(42)
83
Rerefined Auto Lubricating Oils 70(52)
Rerefined Indus-Lubricating Oils 11(53)
Rerefined Industrial Other Oils 2(54)
83(55)
To Figure F-1

* See Table F-1 for key to data sources

TABLE F-1. KEY TO SOURCES OF DATA IN FIGURES F-1, F-2, F-3

Data Item No.	Source of Data Item
1	Table F-2
2	" F-2
3	" F-2
4	" F-2
5	" F-2
6	Figure F-3
7	By difference
8	By difference
9	Table F-4
10	" F-5
11	" F-6
12	" F-2
13	By difference
14	Table F-3
15	" F-4
16	" F-5
17	" F-6
18	" F-3
19	By difference, Table F-3
20	By addition
21	Table F-3
22	" F-3
23	" F-3
24	" F-3
25	By addition
26	Table F-7
27	" F-9
28	" F-10
29	" F-11
30	By addition
31	By addition, F-12
32	By addition
33	By addition
34	By addition
35	Table F-14
36	" F-15
37	" F-12
38	" F-22
39	By addition
40	By addition

TABLE F-1 (Continued)

Data Item No.	Source of Data Item
41	Table F-14
42	" F-15
43	" F-22
44	" F-18
45	" F-14
46	" F-18
47	" F-18
48	" F-14
49	" F-14
50	" F-14
51	" F-15
52	" F-14
53	" F-14
54	" F-14
55	" F-14
A_1	By difference
A_2	" "
A_3	" "
A_4	" "
A_5	" "
B_1	Table F-21
B_2	" F-19
B_3	" F-20
B_4	" F-11
B_5	" F-17
C_1	" F-21
C_2	" F-19
C_3	" F-20
C_4	" F-11
C_5	" F-17
D_1	" F-21
D_2	" F-19
D_3	" F-20
D_4	" F-11
D_5	" F-17
E_1	" F-14
E_2	" F-14
E_3	" F-14
E_4	" F-14
E_5	" F-14
F_1	" F-16
F_2	" F-16
F_3	" F-16
F_4	" F-11
F_5	" F-17

TABLE F-2. SALIENT STATISTICS OF CRUDE PETROLEUM, REFINED PRODUCTS AND NATURAL GAS LIQUIDS IN U. S.-1971 PRELIMINARY DATA[86]

	Thousands of 42 Gal Barrels	Millions of Gal/Yr
Crude Petroleum Production	3,453,914	145,100
Crude Petroleum Imports	613,417	25,800
Refined Products Imports	817,204	34,300
Natural Gas Liquids Production	617,800	25,900
Total Liquids ("Oils") Produced and Imported	5,502,335	231,100
Crude Petroleum Exports	503	21
Refined Products Exports	81,182	3,410
Total Liquids ("Oils") Exported	81,685	3,431

TABLE F-3. ESTIMATED LUBRICATING AND INDUSTRIAL OIL SALES IN THE U.S. - 1970-71[28]

		Millions of Gal/Yr
Automotive Lubricating Oils		1086
Commercial engine oils - fleet sales	200	
Commercial engine oils - retail sales	90	
Factory fills, automotive and farm	60	
Private automobiles*, automobile fleets, other	736	
	1086	
Aviation Lubricating Oils		8
Industrial Lubricating Oils		726
Hydraulic and circulating system oils	325	
Metalworking oils	150	
Railroad engine oils	60	
Gas engine oils	62	
Other	129	
	726	
Other Industrial Oils		377
Process oils	310	
Electrical oils	57	
Refrigeration oils	10	
	377	
Federal Government		37
Exports		487
		2721

* Approximately 600 million gal/yr. (45% = service stations; 17% = car dealers; 10% = garages, auto supply stores; 28% = mass marketers).[87]

TABLE F-4. ESTIMATED MARINE OIL SPILLS - U.S. - 1972[88]

Coast Guard reported oil spills in 1972:

8013 reports of 16.5 millions of gallons

Assume only 75% of spills were reported:

Estimated total marine spills 22 millions of gallons

TABLE F-5. ESTIMATED MARINE OIL LOSSES - U. S. 1971*

Port	Millions of Gallons/Year of Oily Waste Waters Bilge	Cargo Ballast	Cargo Washings	Tanker Ballast	Tanker Washings	Totals
New York	22.3	141.1	3.5	891.3	19.8	1078.0
Hampton Roads	14.2	86.4	0.0	0.0	1.7	102.3
Galveston	6.7	23.1	0.0	0.0	0.0	29.8
Texas City	1.0	0.6	0.0	272.0	38.8	312.4
Houston	25.2	66.2	0.9	1303.2	5.6	1401.1
San Diego	2.2	11.6	0.0	0.0	0.0	13.8
San Francisco	7.1	63.5	0.0	524.7	2.5	597.8
San Juan	3.6	58.7	0.0	14.4	13.0	89.7
Miami	1.3	22.0	0.0	0.0	0.0	23.3
Cleveland	205.8	9.0	0.0	0.0	0.0	214.7
St. Louis	1.3	0.0	2.0	0.0	0.0	3.3
Total	290.7	482.2	6.4	3005.6	81.4	3866.2
% of Total	7.5	12.5	0.17	77.73	2.1	100.00
Projections to National Basis	-----	-----	----	-----	-----	14,838

* Harris Report[8]

Table F-5. (Continued)

Although Frederic R. Harris, Inc. is unwilling to make the following calculations, RECON will do so as a "guesstimate":

Projections of Above Data to National Total:

	% of Total*	Millions of Gal/Yr. Of Oily Waste Water**
Bilge	7.5	1117
Cargo Ballast	12.5	1861
Cargo Washings	0.17	25
Tanker Ballast	77.73	11572
Tanker Washings	2.1	313
	100.00	14,888

* In Ports Surveyed

** Nationally - By Applying %'s to National Total

Estimates of Oil content of the oily waste waters:

	% of Oil Content	Source
Bilge	1.0	Harris Report Above, p. 4-18
Cargo Ballast	0.0	Assumed
Cargo Washings	0.0	Assumed
Tanker Ballast	0.5-2.0	(1) + (2)
Tanker Washings	10.0	Harris Report Above, p. 4-18

Table F-5. (Continued)

(1) Harris Report above, p. 4-18 indicates 2%.

(2) Esso Report for Norfolk reports 0.1-1.0% - assume average 0.5%.

Application of oil content to oily waste quantities:

	Millions of Gal/Yr Waste Water	% Oil	Millions of Gal/Yr Waste Oil
Bilge	1117	1.0	11
Cargo Ballast	1861	0.0	0
Cargo Washings	25	0.0	0
Tanker Ballast	11572	1.25 (avg.)	145
Tanker Washings	313	10.0	31
	14888		187

TABLE F-6. ESTIMATE OF OIL LOSSES AND SPILLS ON LAND, AND LOSSES FROM PROCESSING-1971*

Assume 0.5% of Total Liquids ("Oils")+

0.005 (231,100) = 1156 Millions of Gal/Yr.

---

* Includes oils in waste waters.

+ See Table F-2

TABLE F-7. ESTIMATED LUBE OIL SALES AND WASTE OILS GENERATED AT AUTOMOTIVE SERVICE CENTERS* 1970-1971

	Sales Millions of Gal/Yr.		Waste Oil Factor±	Waste Oil Millions of Gal/Yr.	
Automobiles in service stations	270		0.63	170	
Automobiles in garages & auto supply stores	60		0.63	38	
Automobiles at new car dealers	102		0.90	92	
Retail sales for commercial engines	90		0.63	57	
Automotive fleet and other lube oil uses +	136		0.50	68	
Sub-Total		658			425
Factory fills, automotive and farm	60		0.90	54	
Oil bought at discount stores	168		0.22	37	
Sub-Total		886			516
Commercial engine Fleets	200		0.5	100	
Totals	1086			616	

± See Table F-8 for estimates of waste oil factors.

* Includes motor oils, transmission oils, hydraulic oils, etc.

+ Marine, agricultural, etc.

TABLE F-8. ESTIMATE OF FACTORS FOR CONVERTING AUTOMOTIVE SALES TO WASTE OIL QUANTITIES

Service Stations[2]

70% of oil sold is used for changes.
Oil drained is 90% of filled capacity.
70% x 90% = 63% of oil sold - waste oil generated.

Garages and Auto Supply Stores

Assume average is same as service stations (63%).

New Car Dealers

100% of oil sold is used for changes.
Oil drained is 90% of filled capacity.
100% x 90% = 90% of oil sold = waste oil generated.

Retail Sales for Commercial Engines

Assume same as service stations (63%).

Automotive Fleet and Other Lube Oil Uses

Assume 50%, allowing for two-cycle engines and internal use, e.g. fuel, by commercial and governmental fleets.

Factory Fills, Automotive and Farm

Assume 90% recovery as in automotive service centers.

Oil Bought at Discount Stores

Assume same as service stations (63%).

Assume 35% of waste oil generated finds it way to service stations.*

63% x 35% = 22% of oil sold = waste oil generated at service stations.

* Estimated by RECON SYSTEMS from information obtained by Teknekron[14]

TABLE F-9. GENERATION OF INDUSTRIAL LUBRICATING WASTE OILS

Lubricating Oils	Sales* MM gal/yr.	Factor	Waste Oil MM gal/yr.
Hydraulic & circulating system oils	325	0.42	137
Metalworking oils	150	0.7	105
Railroad engine oils	60	0.53	32
Gas engine oils	62	0.9	56
Aviation and other	137	0.47	64
Totals	734		394

* Sources: See Table F-3.

TABLE F-10. GENERATION OF OTHER INDUSTRIAL WASTE OILS

	Sales* MM gal/yr.	Factor	Waste Oil MMgal/yr.
Process oils	310	0.1	31
Electrical oils	57	0.9	51
Refrigeration oils	10	0.5	5
Totals	377		87

*Source: See Table F-3

TABLE F-11. GENERATION OF U.S. GOVERNMENT LUBRICATION WASTE OILS

Sales* MM gal/yr	Factor	Waste Oil MM gal/yr
37	0.5	18

Assume following distribution of the waste oil:

To the environment	3
For road oils & dust control	4
For fuel	4
To re-refiners	3
To reprocessors	4
	18

* See Table F-3.

TABLE F-12. CONSUMPTION OF LUBRICATING OILS - AS LUBRICATING OIL, FUEL, OR OTHER USES BY ORIGINAL PURCHASER/USER

Assume Consumption = Sales - Waste Oil Generated

	Sales*	-	Waste Oil	=	Consumption
Auto Lubes	1086	-	616	=	470
Industrial & Aviation Lubes	734	-	394	=	340
Other Industrial Oils	377	-	87	=	290
U.S. Government Lubes	37	-	18	=	19
	2234	-	1115	=	1119

* From Table F-3.
+ From Tables F-7, 8, 9, 10, 11.

TABLE F-13. WASTE LUBRICATING OIL REREFINERS
1973 PRODUCTION - RECON SYSTEMS SURVEY *

Company	Total GPD	Total MGPY @ 250D	MGPY Auto Lube Oils	MGPY Industrial Lube Oils	MGPY Other Industrial Oils	MGPY Fuel
1	7,000	1,750	1,575	0	0	175
2	10,000	2,500	2,250	250	0	0
3	12,000	3,000	2,850	150	0	0
4	8,000	2,000	200	1,800	0	0
5	20,000	5,000	5,000	0	0	0
6	6,500	1,625	1,625	0	0	0
7	25,000	6,250	6,250	0	0	0
8	5,200	1,300	520	780	0	0
9	1,800	450	450	0	0	0
10	27,000	6,750	500	0	0	6,250
11	2,000	500	450	50	0	0
12	8,300	2,075	1,971	0	0	104
13	12,000	3,000	2,700	300	0	0

TABLE F-13 (continued)

Company	Total GPD	Total MGPY @ 250D	MGPY Auto Lube Oils	MGPY Industrial Lube Oils	MGPY Other Industrial Oils	MGPY Fuel
14	12,000	3,000	3,000	0	0	0
15	40,000	10,000	9,000	1,000	0	0
16	2,000	500	25	0	0	475
17	22,000	5,500	4,950	0	270	280
18	8,000	2,000	1,800	0	100	100
19	25,000	6,250	5,625	625	0	0
20	6,000	1,500	1,500	0	0	0
21	8,000	2,000	1,800	200	0	0
22	3,000	750	75	0	0	675
23	2,500	625	593	32	0	0
24	4,000	1,000	1,000	0	0	0
25	4,000	1,000	1,000	0	0	0
26	2,000	500	500	0	0	0
27	Strictly a fuel processor --					

TABLE F-13 (continued)

Company	Total GPD	Total MGPY @ 250D	MGPY Auto Lube Oils	MGPY Industrial Lube Oils	MGPY Other Industrial Oils	MGPY Fuel
28	4,000	1,000	1,000	0	0	0
29	6,000	1,500	0	1,500	0	0
30	6,000	1,500	1,350	0	150	0
31	5,000	1,250	0	625	0	625
32	12,500	3,125	2,969	156	0	0
33	5,000	1,250	0	0	1,250	0
34	1,900	475	0	0	475	0
35	10,000	2,500	125	2,375	0	0
	333,700	83,425	62,653	9,843	2,245	8,684
Assuming 90% coverage of the industry:						
	371,000	93,000	70,000	11,000	2,000	10,000

---

* GPD = gallons per day; GPY = gallons per year; MGPY = thousands of gallons per year.
250 D = 250 days per year.

TABLE F-14. ESTIMATE OF FEEDSTOCKS TO WASTE LUBRICATING OIL REREFINERS *

A. Product: Rerefined Auto Lubes 70 MM GPY

Assume plant yield = 65%
Feed = 108 MM GPY (assume 3 MM GPY from U.S. government, 105 MM GPY from other auto sources)

B. Product: Industrial Lubes 11 MM GPY

Assume plant yield = 70%
Feed = 16 MM GPY

C. Product: Other Industrial Oils 2 MM GPY

Assume plant yield = 70%
Feed = 3 MM GPY

D. Product: Fuel 10 MM GPY

Assume plant yield = 90%, and also
Feed = 11 MM GPY

Summary:

Auto Lube Oils	105	MM GPY
U.S. Government Lube Oils	3	MM GPY
Industrial Lube Oils	16	MM GPY
Other Industrial Oils	3	MM GPY
Spills & Losses	11	MM GPY
Total Feed	138	MM GPY
Less Products (A,B,C)	83	MM GPY
Less Internal Fuel Use	11	MM GPY
Less Fuel Sales (D)	10	MM GPY
To Environment	34	MM GPY

* MM GPY = Millions of gallons per year
Product quantities from Table F-13

TABLE F-15. ESTIMATION OF TOTAL FEEDSTOCK TO REPROCESSORS

From Tables F-8 thru F-12, Total Waste Oil = 1115 MM GPY

From A. D. Little Report[2], about 45% of Auto and industrial waste oils is estimated to be reprocessed.

∴ Reprocessed Oil = 0.45 (1115) = 502 MM GPY

From Table F-14, Feedstock to Rerefiners = 138 MM GPY

∴ Feedstock to Reprocessors from these sources = 502 - 138 = 364 MM GPY

From Table F-17, Feedstock from Spills & Losses = 399

∴ Total Feedstock to Reprocessors = 763 MM GPY

TABLE F-16. ESTIMATION OF INDIVIDUAL FEEDSTOCKS TO WASTE OIL PROCESSORS

From Table F-15,

Feedstock from auto , industrial, U.S. Government, waste oils = 364 MM GPY

From Table F-11, Waste oil from U. S. Government = 4 MM GPY

∴ From auto, industrial = 360 MM GPY

Assume same proportion of oil from each of these sources goes to reprocessors

	Waste Oil	%	Waste Oil to to Reprocessors
auto lube oils	616	56.2	202
industrial lube oils	394	35.9	130
other industrial oils	87	7.9	28
	1097	100.0	360 MM GPY

TABLE F-17. DESTINATION OF SPILLS AND LOSSES

From Tables F-4,5,6, Spills and Losses = 1365 MM GPY

It is speculated that 80% of marine oil spills remain in environment.[88] Assume 0.8 (22) = 18 MM GPY.

Recon guesses that 50% of land, marine. and processing losses and land spills (see Tables F-5,6) are entering the environment = 0.5 (187 + 1156) = 672 MM GPY

From Table F-14, amount to rerefiners = 11 MM GPY

∴ By difference, assume balance goes to reprocessors road oils, and directly to fuel 664 MM GPY
1365 MM GPY

Of the 664 MM GPY, assume:

To Road Oils , asphalt	10%	66 MM GPY
To Fuels	30%	199 MM GPY
To Waste Oil Processors	60%	399 MM GPY
Total	100%	664 MM GPY

TABLE F-18. ESTIMATION OF PRODUCTION OF WASTE OIL PROCESSORS

Assume:

80% of production to fuel sales = 0.8 x 763 = 611 MM GPY

10% of production for road oil and asphalt = 76 MM GPY

5% of production for internal fuel use = 38 MM GPY

5% of production to the environment = 38 MM GPY

763 MM GPY*

* From Table F-15.

TABLE F-19. ESTIMATE OF DESTINATION OF INDUSTRIAL LUBRICATING WASTE OILS

From Table F-12, Total industrial lubricating waste oil = 394 MM GPY

From Table F-16, Amount to Reprocessors = 130 MM GPY

From Table F-14, Amount to Reprocessors = 16 MM GPY

∴ Amounts to environment, road oils, and fuel = 248 MM GPY

Guess at distribution:

	%	MM GPY
To Environment	45	112
For Road Oils, Asphalt	10	25
For Fuel	45	111
	100	248

TABLE F-20. ESTIMATE OF DESTINATION OF OTHER INDUSTRIAL WASTE OILS

	MM GPY
From Table F-12, total other industrial waste oil =	87
From Table F-16, amount to reprocessors =	28
From Table F-14, amount to re-refiners =	3
∴ Amount to environment, road oils, and fuel =	56

Guess at Distribution:

	%	MM GPY
To Environment	45	25
For Road Oils , Asphalt	10	6
For Fuel	45	25
	100	56

TABLE F-21. ESTIMATE OF DESTINATION OF AUTOMOTIVE LUBRICATING OILS

From Table F-12, total automotive waste oil = 616 MM GPY

From Table F-16, amount to reprocessors = 202

From Table F-14, amount to re-refiners = 105

∴ Amount to environment, road oil, and fuel = 309

From A. D. Little Report[2], it is estimated that about 23% goes for road oil and dust control =142

∴ To the environment and fuel = 167

∴ From A. D. Little Report[2], assume 24% of total auto waste oil is uncollected and goes to the environment = 148

∴ Amount directly to fuel = 19

TABLE F-22. ESTIMATE OF WASTE OIL POTENTIALLY ENTERING THE ENVIRONMENT

From Table	Source	MM GPY Amount
F-21	Auto lube oils	148
F-19	Industrial lube oils	112
F-20	Other industrial oils	25
F-11	U.S. Government lube oils	3
F-17	Losses & Spills	690
F-14	Lube oil rerefining	34
F-18	Waste oil reprocessing	38
Figure F-3	Road oils (0.88* x 319)	281
	Total	1331 MM GPY

* Estimated from EPA data.[33]

APPENDIX G

HEALTH AND SAFETY ASPECTS OF RE-REFINING PROCESS EFFLUENTS

	Page
Acid Sludge	321
Spent Clay	325
Caustic Sludge	326
Distillation Bottoms, etc.	326
Volatiles, Vapors	326
Noise	327
Other Safety Considerations	327

HEALTH AND SAFETY ASPECTS OF RE-REFINING PROCESS EFFLUENTS

Although the following discussion deals with health and safety aspects of re-refining effluents, much of the data is applicable to the waste oils directly. In additions, some industrial waste oils, e.g. chlorinated biphenyl type transformer oils are inherently hazardous.

The Occupational Safety and Health Standards, Sax's "Dangerous Properties of Industrial Materials", and other suitable references [81,82,83] should be consulted for specific situations.

ACID SLUDGE

In general, acid sludge exhibits the same health and safety aspects as does virgin sulfuric acid. Specifically, it is corrosive, carries a white label (Coast Guard, ICC, and IATA Classifications), and has the following Hazard Analysis:

Toxic Hazard Rating:
Acute Local: Irritant 3; Ingestion 3; Inhalation 3.
Acute Systemic: U.
Chronic Local: Irritant 2; Inhalation 2.
Chronic Systemic: U.
TLV: ACGIH (recommended); 1 milligram per cubic meter of air.

Toxicology: Contact with the body results in rapid destruction of tissue, causing severe burns. No systemic effects due to continual ingestion of small amounts of this material have been noted. There are systemic effects secondary to tissue damage caused by contact with it. However, repeated contact with dilute solutions can cause a dermatitis, and repeated or prolonged inhalation of a mist of sulfuric acid can cause an inflammation of the upper respiratory tract leading to chronic bronchitis. Sensitivity to sulfuric acid or mists or vapors varies with individuals. Normally 0.125 to 0.50 ppm may be mildly annoying and 1.5 to 2.5 ppm can be definitely unpleasant. 10 to 20 ppm is unbearable.

Workers exposed to low concentrations of the vapor gradually lose their sensitivity to its irritant action. Inhalation of concentrated vapor or mists from hot acid or oleum can cause rapid loss of consciousness with serious damage to lung tissue. In concentrated form it acts as a powerful caustic to the skin destroying the epidermis and penetrating some distance into the skin and subcutaneous tissues, in which it causes necrosis. This causes great pain and if much of the skin is involved, it is accompanied by shock, collapse and symptoms similar to those seen in severe burns. The fumes or mists of this material cause coughing and irritation of the mucous membranes of the eyes and upper respiratory tract. Severe exposure may cause a chemical pneumonitis; erosion of the teeth due to exposure to strong acid fumes has been recognized in industry.

Fire Hazard: Moderate, by chemical reaction; a powerful oxidizer; can ignite upon contact with combustibles.

Disaster Hazard: Dangerous; when heated, it emits highly toxic fumes; will react with water or steam to produce heat; can react with oxidizing or reducing materials.

Countermeasures are described in "Dangerous Properties of Industrial Materials."[82]

Due to the complex composition of the acid sludge, there are other noteworthy aspects:

Combustibles

The 30-42 wt.% concentration of combustibles indicates that the sludge should be treated with appropriate caution, but due to the low concentration of volatiles (0.8%), this is probably a minor hazard.

Lead

Because the concentration of lead ranges from 1,000 ppm (as elemental lead) from treating waste diesel oil to 20,000 ppm from treating crankcase waste oils, the sludge probably presents significant potential for lead poisoning, since

1. The lead may be partially present as organolead compounds which can enter the body through the skin.

2. The lead is probably present partially as lead sulfate, one of the most toxic forms (due to high solubility).

3. The concentrations of lead in blood in cases of poisoning are equivalent to about 0.27 grams (6×10^{-4} lb) of sludge!

4. The concentration of lead is comparable to that in lead paint which has been banned or restricted in some areas.

The complete writeup in Sax on lead, lead compounds, and tetraethyl lead should be consulted.[82]

Organometals

No data has been found to indicate the presence of or absence of compounds of the metals with organic constituents of the oils. However, the following hazard analysis from Sax may be appropriate:

Organometals
General Information:

Description: Compounds containing carbon and a metal. Ordinary metallic carbonates (calcium carbonate etc.) are excluded and also metallic salts of common organic acids. Examples of organic metal compounds are Grignard compounds such as methyl magnesium iodide (CH_3MgI) and metallic alkyls such as butyllithium (C_4H_9Li).

Hazard Analysis:

Toxicity: This group of compounds is constantly growing in importance but there is relatively little toxicological information on most of them. Alkyl compounds of lead, tin, mercury and aluminum are known to be highly toxic. Less is known about other organometals, but for the most part they are highly reactive chemically and therefore dangerous if only on direct contact. Until specific toxicological data become available, it is prudent to exercise great caution in handling organometals, particularly the alkyl forms.

Sulfonates

No data has been found to indicate the presence or absence of sulfonates in the acid sludge, although it can be speculated that they are present. Sax indicates that the toxicity varies for different compounds. Toxic fumes of sulfur oxides may be emitted on decomposition.

Calcium

The toxicity of calcium compounds generally is slight; in fact many calcium compounds are used medicinally.

Phosphorus

Organic phosphate compounds are considered poisons by ICC (Poison B Classification) and IATA (Poison B Classification).

Most inorganic phosphates, except phosphine, have low toxicity, but in large doses may cause serious disturbances particularly in calcium metabolism. Meta phosphates may be highly toxic, causing irritation and hemorrage in the stomach as well as kidney and liver damage. No data has been found on the hazards of the low concentrations present in the acid sludge.

Sodium

Sodium compounds in general are not toxic unless the anion is, because the sodium ion is practically non-toxic.

Zinc

Zinc is not inherently a toxic element, and zinc compounds generally are of low toxicity.

Carcinogenicity

Some polycyclic hydrocarbons, which may be present in some oils, have carcinogenic properties.[84] These include 3,4-benzpyrene, 1,2,3,4-dibenzphenanthrene, 3,4,8,9 dibenzpyrene, and 3,4,9,10 dibenzpyrene. Possible toxicity and carcinogenicity of lubricants and additives has also been investigated.[85]

Other Metals

In addition to the above, acid sludge also contains copper and chromium in minor amounts. EPA has included these elements in the list of substances which, on the basis of initial analyses are believed to have potential for producing serious public health and environmental problems when contained in wastes for disposal. Asbestos, arsenic, beryllium, cadmium, cyanides, lead, mercury, halogenated hydrocarbons, pesticides, selenium, and zinc are also on the list.

The other known constituents of the sludge do not appear to present any obvious hazard potentials.

SPENT CLAY

No analyses of spent clay have been found. Spent clay for petroleum refining contains 1-45% oil. It should be pointed out that it is possible that the adsorped oil contains lead and other potential hazards, as outlined in Section VIII, and care should be taken to prevent entry into the body of the oil laden clay.

The Material Safety Data Sheets received from clay suppliers claim that:

1. Attapulgus clay is not considered a hazardous material under current Department of Labor definitions. Source: Englehard Minerals & Chemicals Division.

2. Bentonite clay is considered an irritant due to its particulate nature; with a 15 ppm (for respirable fraction of inert dust) threshhold limit value. Safety glasses and gloves and protective equipment, and water flushing for eye and skin contamination, and vomiting inducing for internal contamination are recommended. Landfill is suggested for waste disposal. Source: Ashland Oil, Inc.

Since the clays contain major portions of silica (e.g. Georgia Kaolin "Clarolite T-60" contain 64.6% SiO_2) Sax's writeup on silica should be consulted. OSHA limits on mineral dusts should also be consulted.[81]

Based on our understanding of the function of the clay (to remove odor and color bodies), we expect that the adsorbed compounds include nitrogen and oxygen containing organics. Sax's writeups on nitro compounds of aromatic hydrocarbons, sulfur compounds, aldehydes, esters, and ketones should be consulted.[82]

Due to the oil content, the spent clays may present a fire hazard.

CAUSTIC SLUDGE

Caustic sludge resulting from oil treating should be treated with the same precautions as virgin caustic. Specifically, it is corrosive, carries a white label (in solution), and has a "hazardous material" Coast Guard Classification. Consult Sax for writeups on caustics and alkalies.[82]

Lead, other metals and metal compounds, and combustible oils present in the sludge would appear to present the same potential health and safety problems as the acid sludge.

Sodium silicate is known to be present, but this compound, commonly referred to as water glass, has a "slight" hazard rating according to Sax.

Sodium compounds in general are not toxic unless the anion is, because the sodium ion is practically non-toxic.

DISTILLATION BOTTOMS, RAW OIL SPILLS, TANK SLUDGES, PROCESS RESIDUES, AQUEOUS WASTE

Previous and subsequent discussions on lead, combustibles, organometals, other metals, volatiles, and carcinogenicity would appear to apply to these waste products.

Phenols may be found in wastes from distillation overheads. Consult Sax for hazard analysis of phenols.[82]

VOLATILES, VAPORS

Volatiles and vapors from effluents, spills, and processing steps present health or safety problem potentials if TLV (threshhold limit value in air) is exceeded, or if concentrations reach the flammability range. No data is available on work area concentrations, but TLV data on expected compounds follow:

	TLV
NO	25 ppm
NO_2	5 ppm
SO_2	5 ppm
NH_3	50 ppm

Consult Sax for hazard analyses for NO, NO_2, SO_2 and NH_3.

In addition, attention is again called to Sax's write-ups on aldehydes, ketone, esters and nitro-aromatics, and writeups on paraffins and olefins.[82]

NOISE

It should be noted that noise problems of re-refiners are similar to those of petroleum refineries (e.g. pumps, valves and burners).

OTHER SAFETY CONSIDERATIONS

Safety hazards of re-refining are noteworthy, but normal as compared to refinery operations, except that less instrumentation and more manual operations are involved. Fewer volatile combustibles are present in re-refining.